The American Journal of Surgery

EDITED BY THURSTON SCOTT WELTON, M.D.

February 1945

TRAUMATIC SURGERY

Papers Read at the June 1944
Meeting of The American Association
for the Surgery of Trauma

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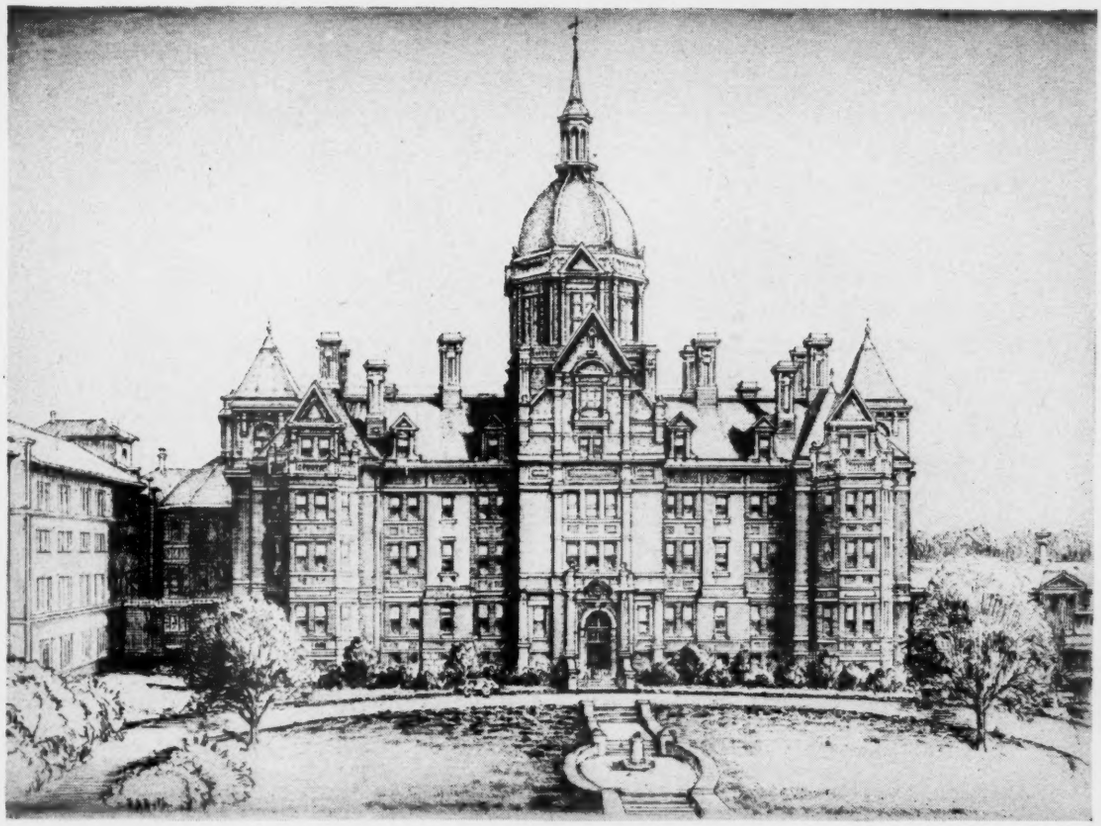

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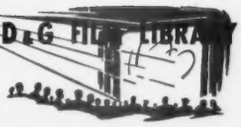

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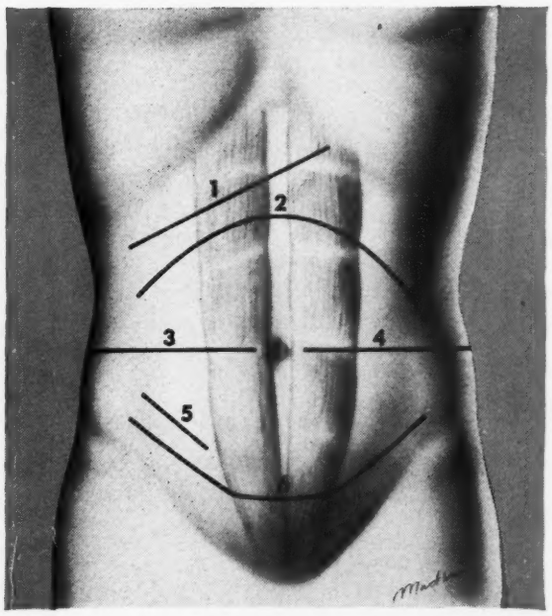

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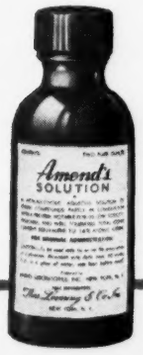

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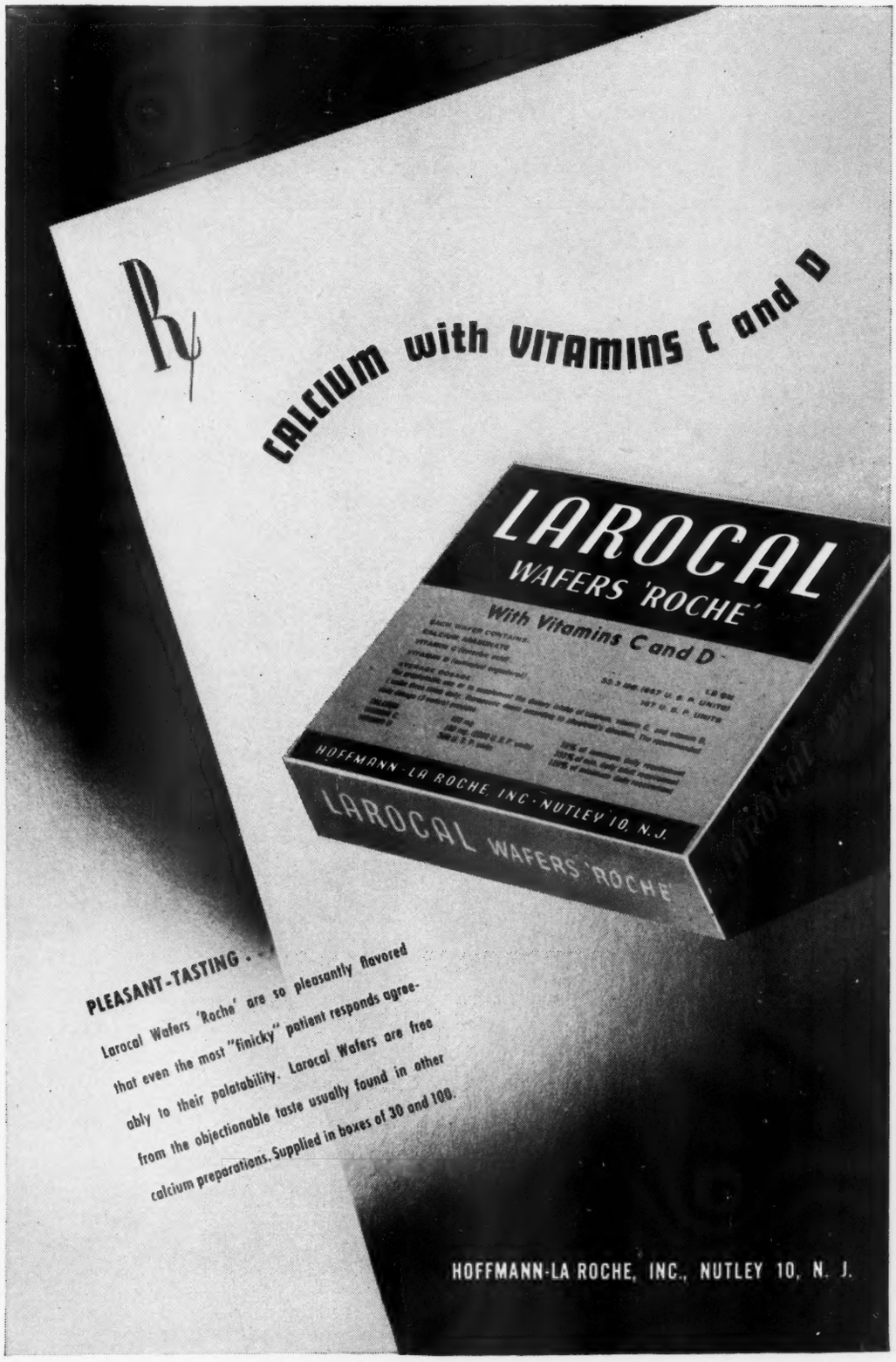
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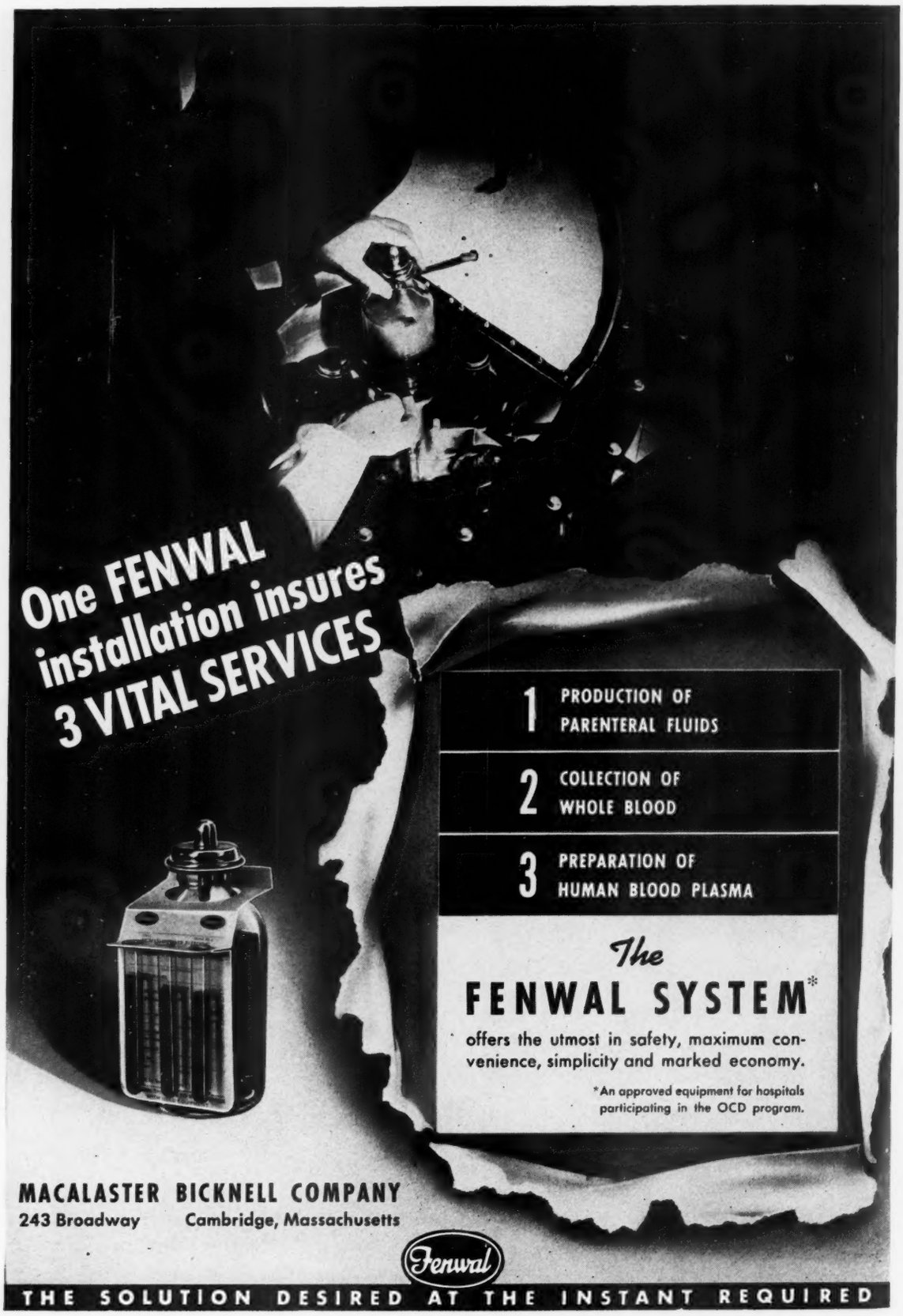
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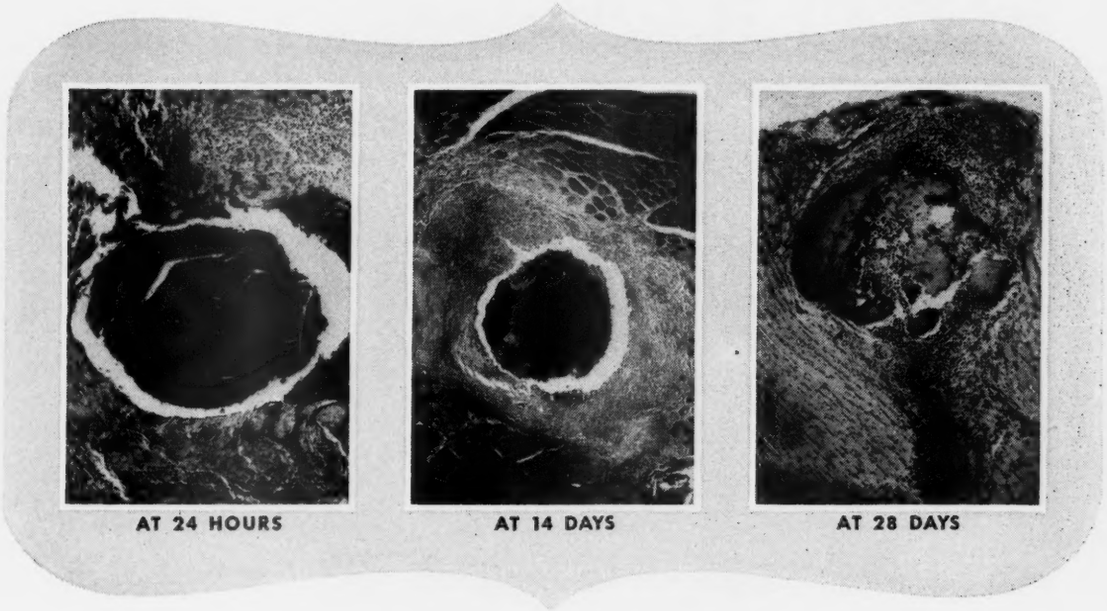

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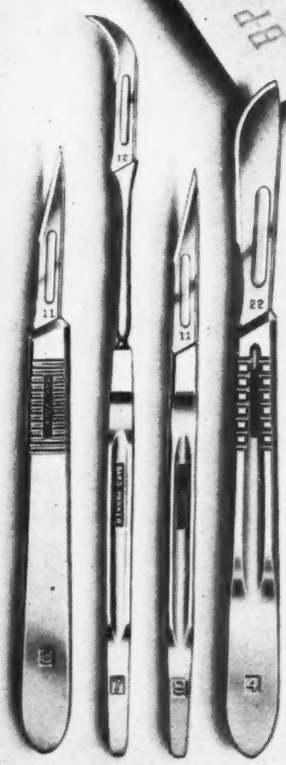

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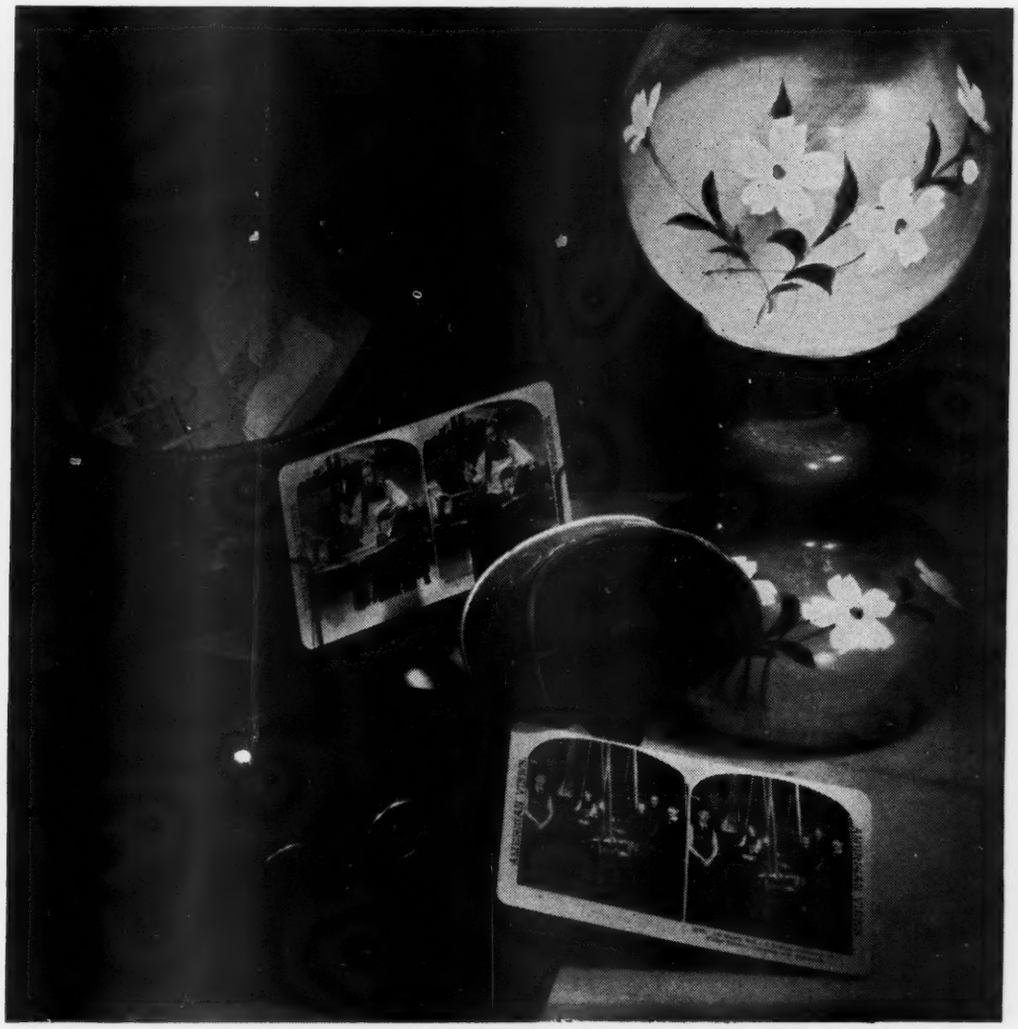

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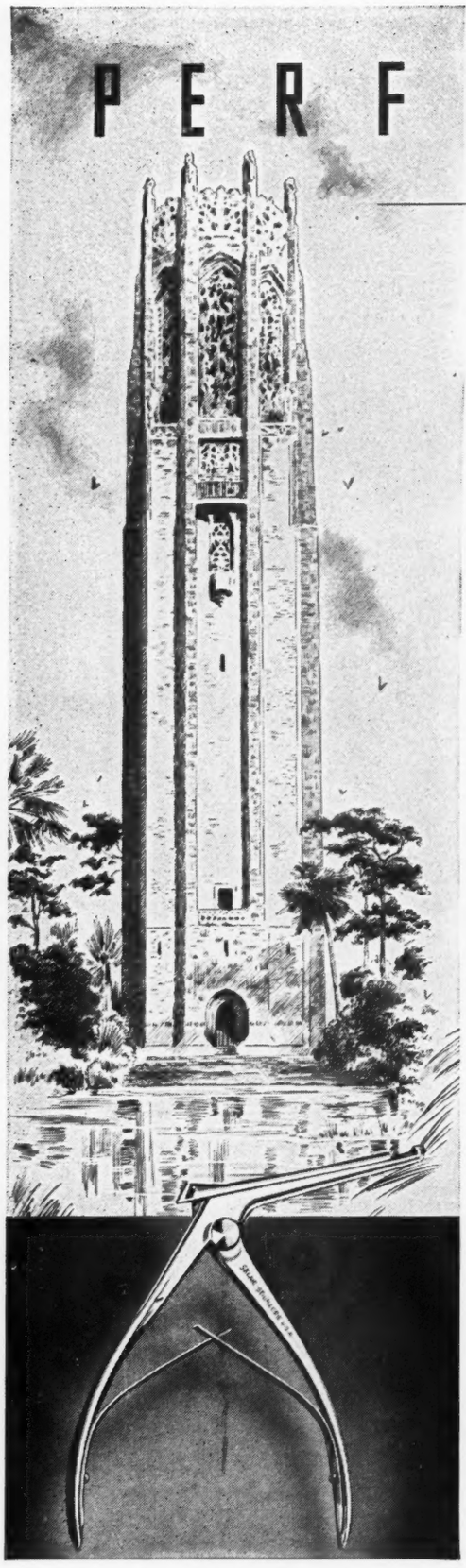

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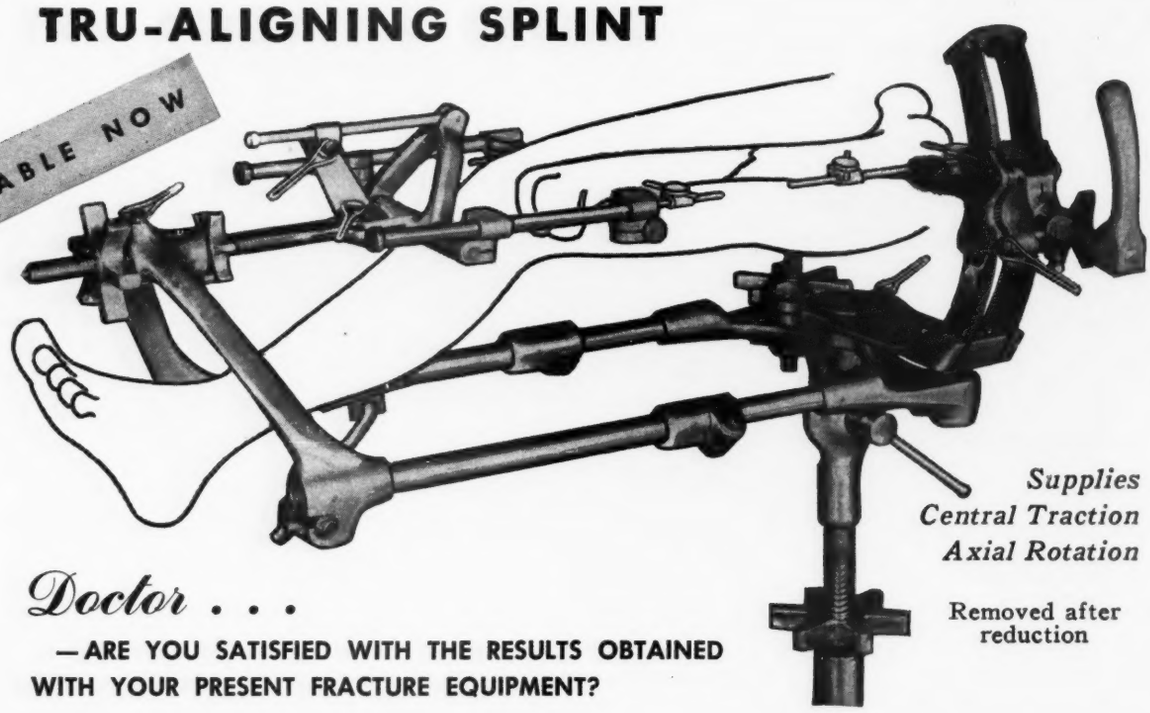

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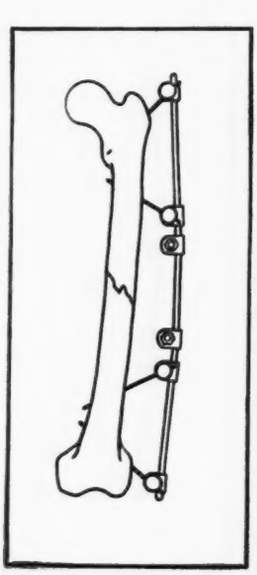

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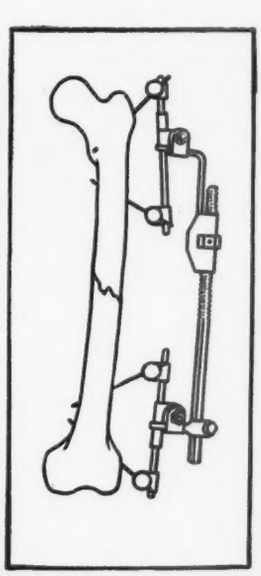

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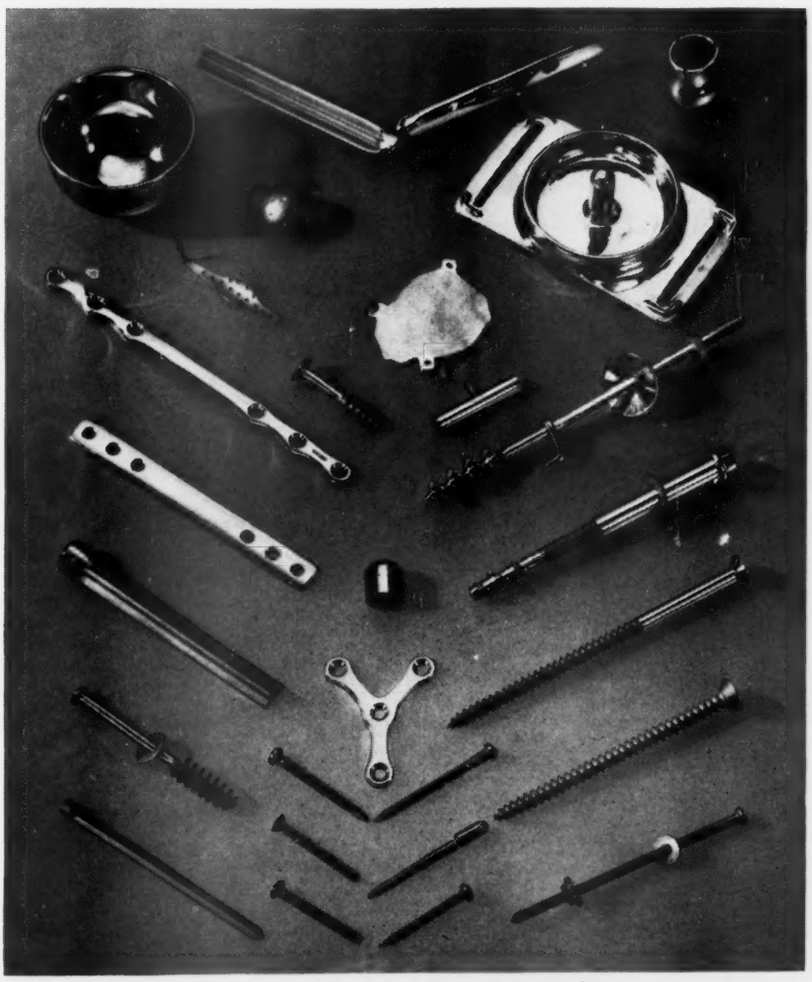

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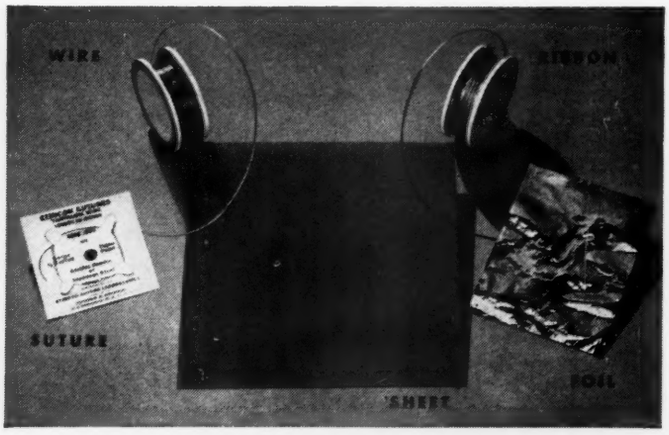
"I have used tantalum wire suture material on all our hand injury cases for the past year and have a large series of them to look back upon. I have used the tantalum wire for both buried and cutaneous suturing. In this fairly large series of cases I have not yet seen any evidence of anything but minimal tissue reaction. I have not yet had a single infection in any of the cases where tantalum wire was used in these hand cases, which, to me, is quite remarkable because I am sure you will appreciate how difficult it is to obtain bacterial and physical cleanliness in working with the hand of the factory worker.*"



*Olson, C.T.: "The Place of Tantalum in Surgery," Industrial Medicine, 13: 917, November, 1944.

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ETHICON SUTURE LABORATORIES
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Smaller "A-11 MODEL"
of the SINGER SURGICAL STITCHING INSTRUMENT

So valuable have the contributions of the Singer suturing instrument proved in facilitating suturing technique, that the range of the Standard Model has now been supplemented through the introduction of a new, smaller "A-11 Model".

This highly perfected product of engineering design and clinical research brings to the field of more delicate surgery all the time-saving advantages and the wide stitch versatility of the Standard Model. Its particular feature lies in its ability to use a selection of ten smaller needles, down to the finest size practicable in surgical work. Subcutaneous suturing becomes possible under conditions of maximum visibility.

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— unites needle, holder, suture supply, and severing edge in one self-contained instrument, sterilizable as a complete unit.

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Surgical Stitching Instrument Division A-25
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Without obligation, send copy of illustrated brochure, with full data on the new Smaller A-11 Model.

Name_____

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Case A.C.

Case A.C.
SYMPTOMS: Sore throat - pain on swallowing
Temperature 100-102°
BACTERIOLOGICAL FINDINGS: Throat culture showed hemolytic streptococci
DIAGNOSIS: Acute ulcerative stomatitis
TREATMENT: One White's Sulfathiazole Gum Tablet chewed for ½ hour every 2 hours for 6 doses
RESULTS: Immediate improvement - lesions healed and temperature normal after 72 hours

White's

THIS actual case report typifies the response to this new, effective method of providing local chemotherapy in oropharyngeal infections. Further indications include acute tonsillitis and pharyngitis, septic sore throat, infectious gingivitis and stomatitis caused by sulfonamide-susceptible microorganisms. Also suggested in the prevention of local infection secondary to oral and pharyngeal surgery.

Important: White's Sulfathiazole Gum provides a *high, sustained* salivary concentration of locally active sulfathiazole (70 mg. per cent)—with negligible systemic absorption. Even with maximal dosage, blood levels seldom approach a level of 0.5—1 mg. per cent. Thus untoward systemic reactions are clearly obviated.

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The Special Liver Fraction used as the base of Beta-Concemin provides the *complete* B complex.

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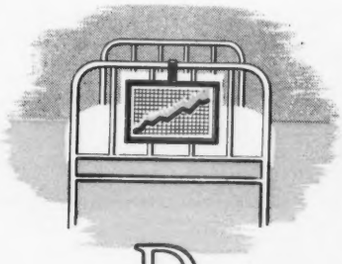
THE WM. S. MERRELL COMPANY CINCINNATI, U. S. A.



WHEN FLAMES OF HYPERMETABOLISM FEED ON BODY PROTEINS . . .

DEPLETION of the protein depots is a constant threat during fever, and in many cases diet alone is inadequate to compensate for the increased nitrogen loss. Parenamine, parenterally administered, effectively restores and maintains positive nitrogen balance in most cases; thus it speeds recuperation—aids in preparing the patient for surgery and in shortening convalescence.

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Amino Acids Stearns
PARENTERAL

FOR PROTEIN DEFICIENCY

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ADMINISTRATION may be by the intravenous, subcutaneous, or intrasternal route.

PARENAMINE is assiduously checked by laboratory procedures, animal testing, and injection of full therapeutic doses clinically to ensure its uniformity, sterility, and freedom from pyrogens.

INDICATED in protein deficiencies and conditions of restricted intake, increased need, or excessive loss of proteins. Particularly useful in preoperative and postoperative management, pregnancy, extensive burns, delayed healing, gastro-intestinal disorders, cirrhosis, nephrosis, fevers and other hypermetabolic states.

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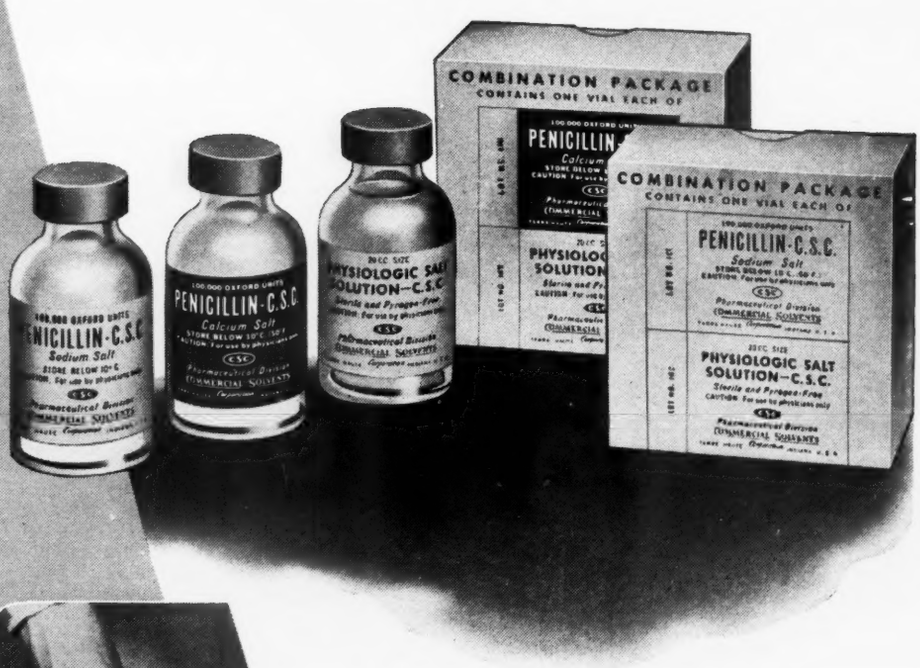
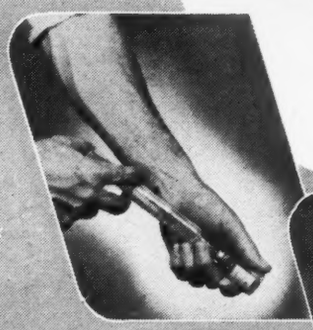
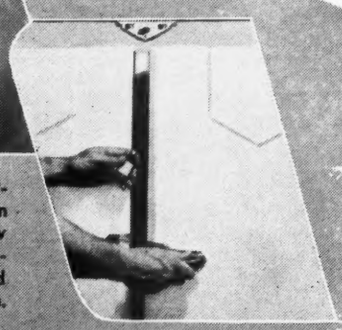
The Combination Packages of





For the usual concentration (5000 Oxford Units per cc.) inject 20 cc. of physiologic salt solution into the vial in the usual aseptic procedure.

Invert the vial and syringe (with needle in vial), and withdraw the amount of penicillin solution required for the first injection.



Store vial with remainder of solution in refrigerator. Solution is ready for subsequent injections during the next 24 hours.

PENICILLIN-C.S.C.

For administration in the physician's office or in the patient's home, Penicillin-C.S.C. will be available in a convenient combination package, as soon as the drug is released for unrestricted use in civilian practice. This combination package provides two rubber-stoppered, serum-type vials. One vial contains enough physiologic salt solution to permit the withdrawal of 20 cubic centimeters. The other vial contains 100,000 Oxford Units of penicillin sodium or penicillin calcium* respectively.

The physiologic salt solution is sterile and free from fever-producing pyrogens. Penicillin-C.S.C.—whether the sodium salt or the calcium salt—is bacteriologically and biologically assayed to be of stated potency, sterile, and free from all toxic substances, including pyrogens, as attested by the control number on the package.

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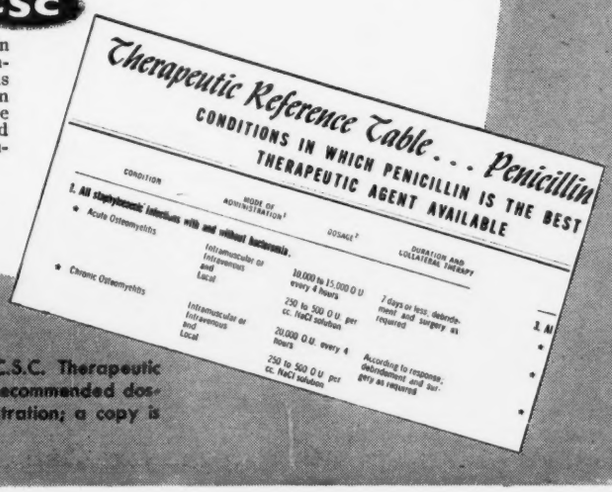
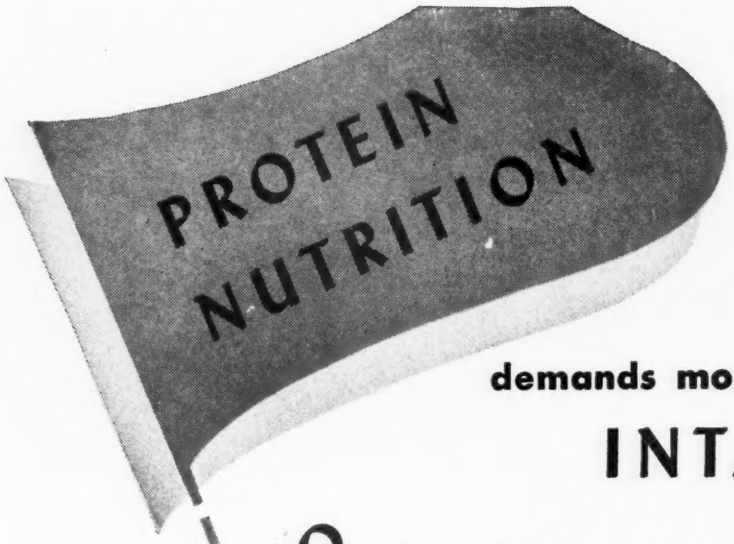
*Penicillin calcium, equal to penicillin sodium in therapeutic efficacy and nontoxicity, in recent investigations has been shown to be less hygroscopic than the sodium salt, and somewhat more stable. Both forms of the drug should be stored in the refrigerator, at a temperature not over 50° F. (10° C.).


Therapeutic Reference Table . . . Penicillin

CONDITIONS IN WHICH PENICILLIN IS THE BEST THERAPEUTIC AGENT AVAILABLE

CONDITION	MODE OF ADMINISTRATION	DOSAGE	DURATION AND COLLATERAL THERAPY
1. All staphylococcic infections with and without bacteremia.			
• Acute Osteomyelitis	Intramuscular or Intravenous and Local	10,000 to 15,000 O.U. every 4 hours	7 days or less; debridement and surgery as required
• Chronic Osteomyelitis	Intramuscular or Intravenous and Local	250 to 500 O.U. per cc. NaCl solution. 20,000 O.U. every 4 hours 250 to 500 O.U. per cc. NaCl solution	According to response; debridement and surgery as required

A page of the "Penicillin-C.S.C. Therapeutic Reference Table," showing recommended dosages and modes of administration; a copy is yours for the asking.



demands more than

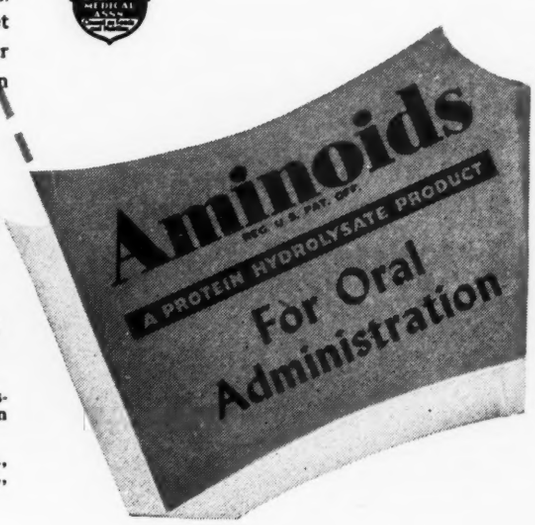
INTAKE

Often, superabundant ingestion of protein-rich food fails to influence a negative nitrogen balance, since nitrogen requirement is not only quantitative, but also qualitative. Among the factors determining the nutritive value of a protein food are its digestibility . . . availability of its amino acids . . . ability of the individual to assimilate the food ingested.

Tests show that intact protein introduced directly into the jejunum, requires 40 to 50 minutes for complete absorption, while protein hydrolysate introduced in the same manner practically disappears completely in *15 to 25 minutes*.**

AMINOIDS*, derived by enzymic digestion from Beef, Wheat, Milk and Yeast and containing all the amino acids in the source material, including those termed essential, is a readily assimilable protein hydrolysate.

AMINOIDS is readily soluble in hot or cold liquids, is not a drug, and may be administered to meet the patient's need for restoring or maintaining a positive nitrogen balance.



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Arlington

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*The name AMINOIDS is the registered trade mark of The Arlington Chemical Company.

**McGee, L. C., and Emery, E. S., Proc. Soc. Exptl. Biol. and Med., 45,475 (1940).

Quoted

from one of more than 600 published papers

"Of our 906 cases from 1939 to June 1943,
we had one fatal case in which the death
was most likely due to pentothal anaesthesia.
Even in that case we are convinced that if
the pentothal had been given properly the
fatal end could have been avoided."

I. Rachmel, M.D.

● *Pentothal Sodium Anaesthesia*
The Canadian Medical Association Journal
50:443, May, 1944

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Pentothal
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Sodium

[SODIUM ETHYL (1-METHYL-BUTYL) THIOBARBITURATE, ABBOTT]

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Address inquiries to
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North Chicago, Illinois

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IT IS axiomatic that virtually all wounds are contaminated and thus susceptible to infection.

Since the presence of infection retards wound healing, its prevention is a powerful factor favoring healing.

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Azochloramid requires a minimum of medical attention and dressing changes. It is a convenient and economical means of combatting infection in most types of contaminated lesions.

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Ipral TRADEMARK CALCIUM

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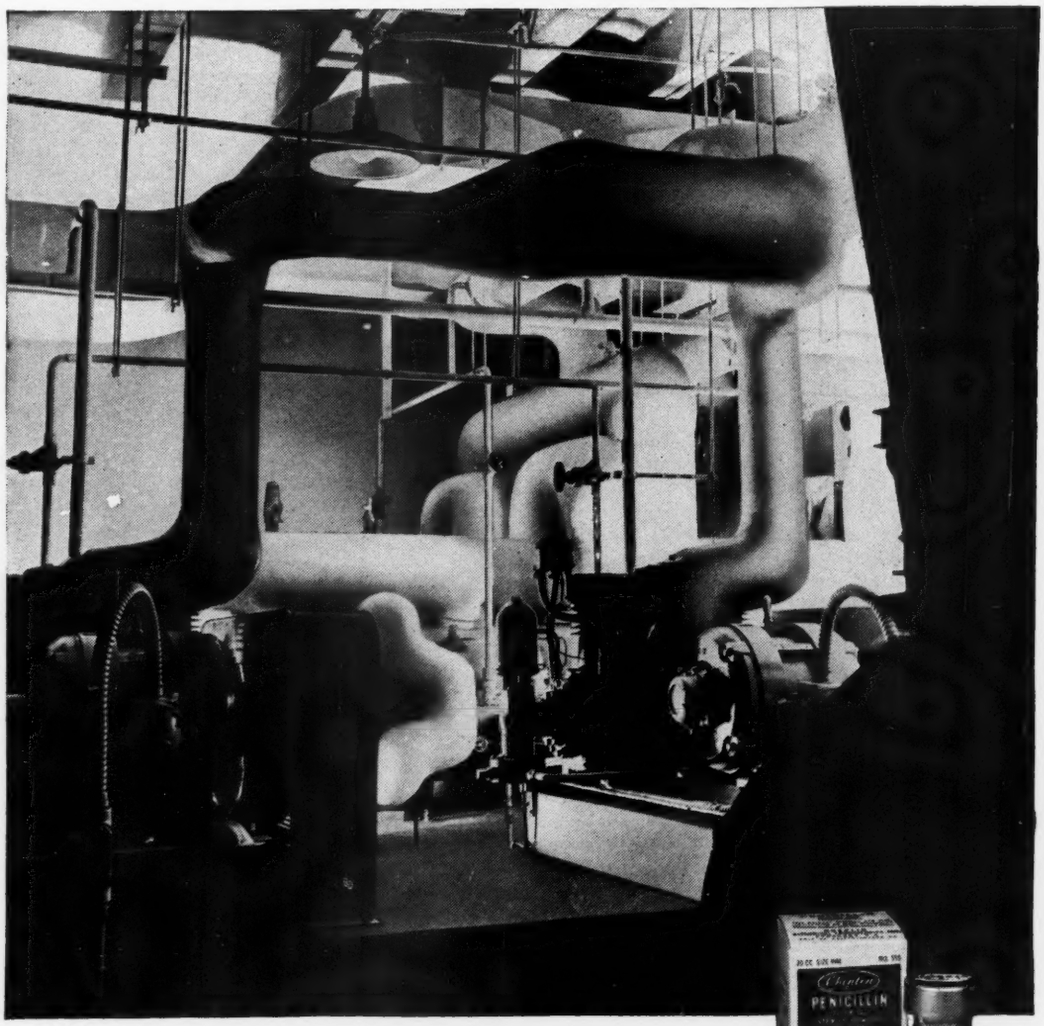

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Bring back Paracelsus and his crucibles today... show him the clinical picture of Penicillin... take him on a trip through a great Penicillin plant like that of Cheplin Laboratories. What would he think? Your guess is as good as ours!

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Who can state Medicine and the Pharmaceutical Manufacturer aren't working together for a better post-war world? And Cheplin is doing its bit!

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PRIODAX

1 is not a phenolphthalein derivative.

2 is well tolerated . . . less likely to produce gastro-intestinal disorders such as nausea, vomiting and diarrhea.

3 is simple to administer . . . a single dose of six tablets is sufficient.

4 produces clear, dependable cholecystograms . . . contains 51.5 per cent of iodine, sufficient to produce adequate shadow density.

5 avoids the possibility of confusing intestinal shadows because it is rapidly absorbed from the small intestine . . . little, if any, reaching the colon.

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the *six tablet* contrast medium for

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PRIODAX*, beta-(4-hydroxy-3, 5-diiodophenyl)-alpha-phenyl-propionic acid, is available in envelopes of six tablets, in boxes of 1, 5, 25 and 100 envelopes.

SCHERING CORPORATION
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. . .

Petrogalar gently, persistently, *safely* helps to establish "habit time" for bowel movement. An aqueous suspension of pure mineral oil each 100 cc. of which contains 65 cc. pure mineral oil suspended in an aqueous jelly, Petrogalar is evenly disseminated throughout the bowel, effectively penetrating and softening hard, dry feces, resulting in comfortable elimination with no straining and no discomfort.

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Five types of Petrogalar provide convenient variability for individual needs. Constant uniformity assures palatability and normal fecal consistency.

. . .

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Petrogalar
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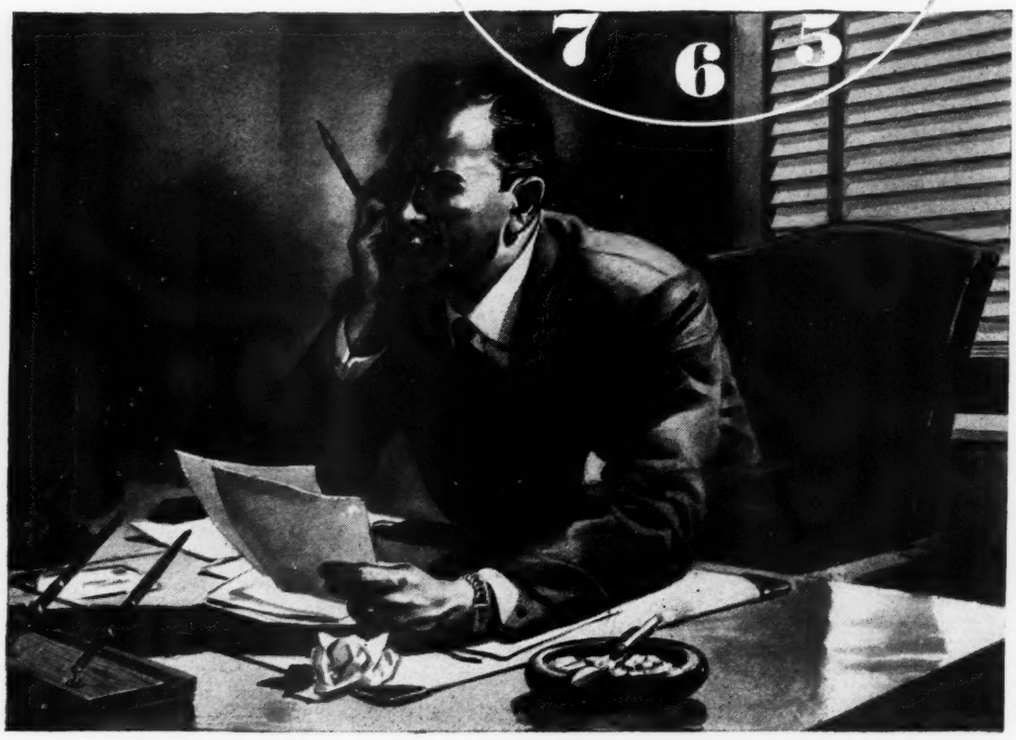
helps establish "Habit Time"



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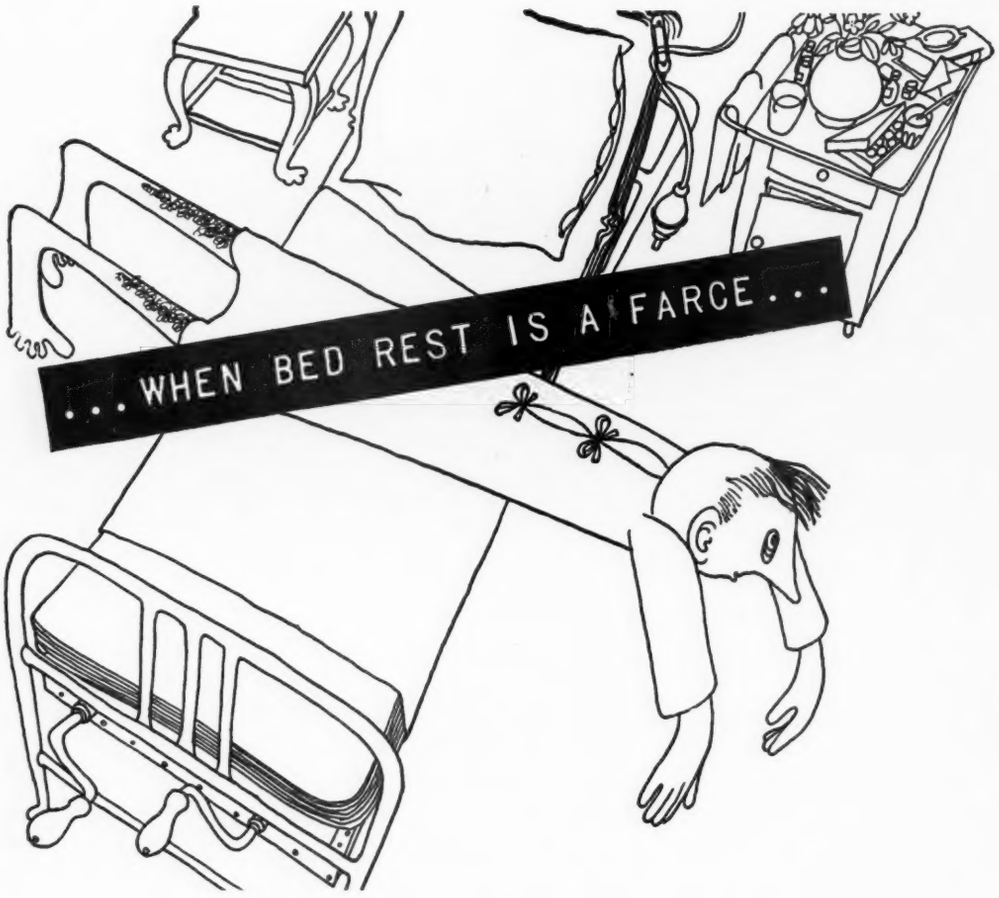
'TABLOID' *Empirin* COMPOUND

Bottles of 100 and 500



To attempt by sheer force to evacuate a constipated bowel may jeopardize the already precarious condition of hypertensive cardiac, tubercular and other patients on bed rest.

Prophylaxis or sensible physiologic therapy of constipation can do much to advance the well-being of such patients. This may be deftly accomplished with 'AGAROL'* Emulsion, which, by replacement of moisture and mucin-like lubricating factors, and by effecting gentle stimulation of peristalsis aids in reestablishing the mechanism of normal evacuation. *Trademark Reg. U.S. Pat. Off

'Agarol'

Emulsion of mineral oil and an agar-gel with phenolphthalein

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A PRACTICAL JOURNAL BUILT ON MERIT

Fifty-fourth Year of Continuous Publication

NEW SERIES VOL. LXVII FEBRUARY, 1945 NUMBER TWO

Editorial

PRESIDENTIAL ADDRESS

CHARLES S. VENABLE, M.D.

Diplomat of the American Board of Surgery

SAN ANTONIO, TEXAS

WHEN I stood with the Founders of this Association in San Francisco I never dreamed that I would be the successor to such predecessors as Kellogg Speed, Edward Gilcreest, Fraser Gurd and Henry Marble.

Trust and confidence of our contemporaries, as expressed in the appointment to the leadership of an organization and a group like this, is the greatest honor that any man can have, and I feel it as deeply as that. I want you to know that this expression is cherished more than any I have ever known.

I do not like addresses, so for that reason I am going to omit the address and instead discuss one of the phases in bone surgery in which I have been particularly interested, and which has taken quite a period of time to develop, to my satisfaction at least. I hope there may be some help in it as we all go along in the same thought and in the same effort, trying to reach a goal to do the best kind of work for the greatest number of people.

I am going to discuss the absence of the excess of new bone growth, meaning callus, as we generally term it, in the presence of completely rigid fixation of bone fragments using metals without chemical irritation by internal fixation.

For a very long time—and I will quote Potts and Palmer and Orr and a good many others dealing with the influence of motion on the healing of fractures—a hematoma was considered a trellis for callus, and also an irritant for hyperemia and new capillaries.

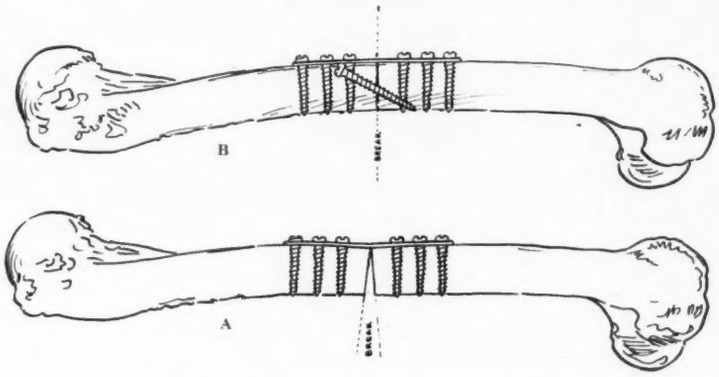

FIG. 1. A, *Mike:* Properly plated femur showing inverted v between fragments. B, *Ike:* Plated the same, but showing the posterior corticis held together firmly with transfixion screw.

Of course, during this period of both external and internal fixation, ideas have been brought forth to keep the bones fixed and immobilize the fracture. Palmer, in 1935, said that perfect immobilization to protect the matrix was essential to bone repair. I think he was perfectly right. Orr said that delayed or non-union was dependent upon a primary factor of insufficient splinting or fixation.

It has been impossible, with external fixation, to maintain that complete fixation of which I speak, so we have gone to internal fixation with plates and screws and other gadgets.

I was particularly interested in Dr. Murray's discussion and exhibition of using long wire in the fixation of fractures and to observe that those fractures which he fixed, which were perfectly immobilized by his long wire method, showed practically no excess of bone growth because of that perfect fixation.

So, if I may, I am going to introduce to you my two old friends, Mike and Ike, who always travel with me. (Figs. 1A and B.)

Mike's femur is properly plated and shows, with the weight only of the femur, much less than of the thigh and the leg below in extension, what happens due to the spring of the plate. This will happen with any kind of plate or bone graft or anything you use. All are familiar with the inverted v-shaped space between the plate and the lower margin of the femur across which new bone growth must

pass through the trellis of fibrin and early capillaries finally to make bone. So, in the event that a femur is plated in this manner, which is usual, one figures roughly a ten, twelve or fifteen week period for this union to be sufficient for weight bearing.

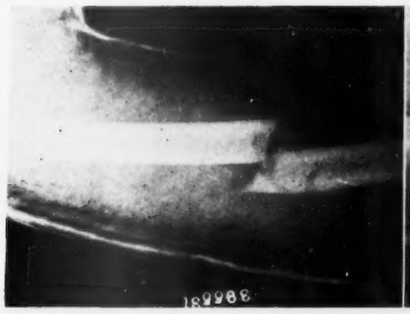

FIG. 2. Transverse fracture of humerus with multiple comminution of upper fragment.

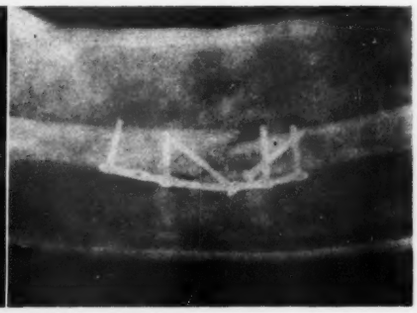

FIG. 3. Same case; fragments separately fixed to shaft with transfixion screw and plate fixing fracture and fragments over all.

In Ike, I have put what we choose to call a transfixion screw. This screw operates obliquely from the upper surface of the proximal fragment through the under surface of the lower fragment across the long axis of a transverse fracture.[1] Entire rigidity at the fracture site cannot be had by a single onlay splint (plate or graft) alone. Cross fixation is absolutely necessary to prevent rocking and torsion as any good carpenter will tell you. Dr. Clay Murray[2] and I have agreed on that principle and preached it for years. Our only difference is that he prefers to do it sideways, while I like from the above downward method best, meaning to use the pull-together force of the screw in the axis of greatest strain. With a patient on his back, that strain is from above downward and were he put to bed on his side, the strain would be sideways. No one will stand at the foot of the bed and twist the poor fellow's foot anyway. You can readily see how tightly the inferior border of the lower fragment is held against the lower margin of the upper fragment in the instance of Mike as compared with the separation in the instance of Ike. Of course, in the case of oblique fractures, transfixion must be directly across the line of the fracture. In such cases, one or two screws well placed usually are sufficient without the addition of a plate.

Our wide difference is I am convinced, and time has proven, that the entire absence of corrosive effect (electrolytic action) is essential to bone tolerance and the terminal holding factor of screws in bone

during the crucial six or eight weeks in which bone is forming across the fracture line. Dr. Murray emphasizes that the thread of the screw, the exactness of application, the dower of the tip, though it

FIG. 4. FIG. 5.

FIG. 4. Femur deliberately shortened by osteotomy and excision of a segment with application of a transfixion screw and plate, September 28, 1942.

FIG. 5. Shows same case November 27, 1942, with firm union without callus.

touches neither sides, top nor bottom of the drill hole through which it passes, the resistant strength to strain or torsion, though minimized by exterior supports, are of first consideration, while at the same time he has the steel that he uses specially made passive in boiling nitric acid in order to create a veil of resistance against corrosion. I think my statement in 1936[3] that electrolytic action is the controlling factor in internal fixation of fractures is basically sound and, though met with skepticism, is proved today. No less important, as we both point out, is that early function of adjacent joints in counterbalance may be secured, which is so necessary for the physiological process of new bone growth in its early stages.

Regard for the anterior curve of the femur should always be had. Therefore, the plate must be bent to conform, instead of making the femur conform to the straight plate, which by virtue of its "spring" alone tends to separate the opposite side of the fracture to the inverted v position without contact.

What I propose to demonstrate is that with such completely rigid fixation there is very early union in which there has been a saving of some 20 to 30 per cent in time in obtaining firm union

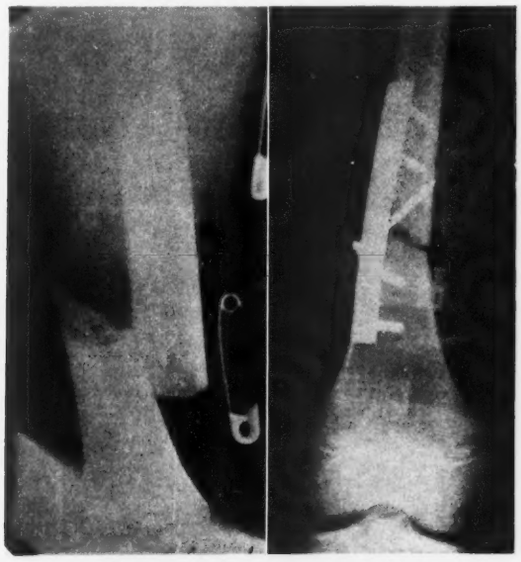

FIG. 6. FIG. 7.

FIG. 6. Semi-oblique fracture of lower third of the femur.

FIG. 7. Fixation with transfixion screw plus a plate, November 16, 1943.

without excess of callus, the presence of which proves local irritation.

The first two illustrations (Figs. 2 and 3) show the fracture and fixation of a humerus which was comminuted with one very large fragment free. There is a vitallium transfixion screw through the upper fragment, which was separated, and another through the fracture with a plate over all. The bend in the plate can be seen to fit the contour of the bone fragments.

Bending does not lessen the strength of plates made of vitallium because the change in molecular arrangement does not change its complete passivity. Vitallium may now be bent without fear of breaking as each vitallium piece (screw, plate or what not) is now *x*-rayed, because vitallium is a cast metal and each article must be devoid of flaws, while its complete tolerance in bone and tissue is the same as it has always been.

Figures 4 and 5 demonstrate a case of deliberate shortening of a femur by osteotomy and excision of a segment with application of a transfixion screw and plate for repair. The date of the operation

was September 28, 1942, while the second skiagram taken on November 27, 1942, shows that weight-bearing union had occurred in sixty days.

FIG. 8. Same case as in Figures 6 and 7 January 16, 1944, with firm union in eight weeks and no excess bone growth.

The third case (Figs. 6, 7 and 8) shows a semi-oblique fracture in the femur in the lower third with fixation done on November 11, 1943. At that time a transfixion screw was placed in addition to a plate and there is quite a space between the fracture ends, which was due to the presence of a small marginal piece of cortical bone. In the next skiagram taken on December 15th, however, one sees quite a bit of new bone between the fracture ends yet no callus around the cortex, while on January 16, 1944, union is apparent, weight bearing was had and knee function was unimpaired.

Figures 9, 10 and 11 demonstrate another fracture of a humerus with quite a large fragment displaced mesially which was pulled into the line of fracture and fixed with one transfixion screw after which a plate was placed over all on September 14, 1942. Eight weeks later, on November 11th, it can be seen that union is complete with a moderate amount of callus on the anterior margin where the fragment was pulled into line.

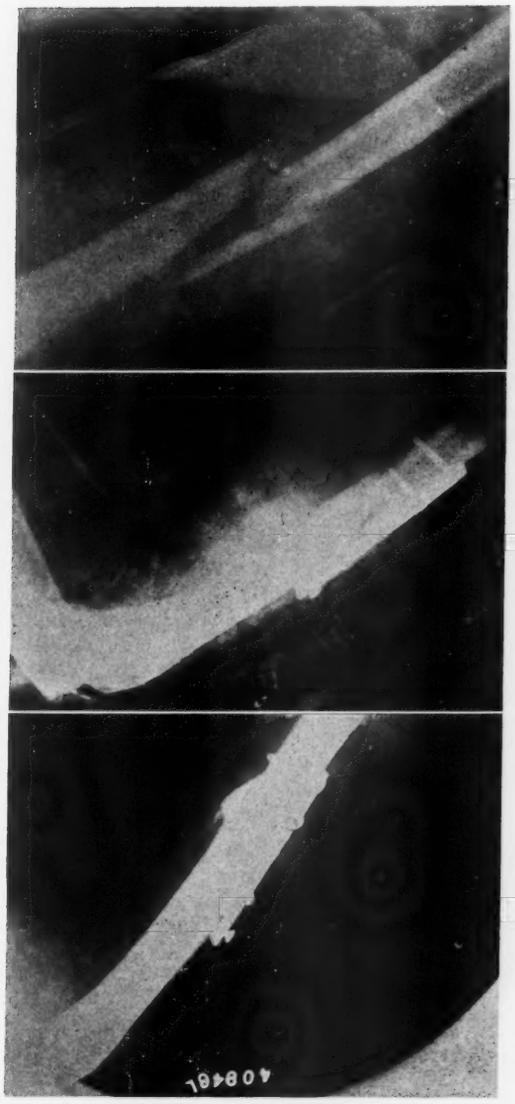

FIG. 9.

FIG. 10.

FIG. 11.

FIG. 9. Another comminuted fracture of the humerus of which large mesial fragment was displaced.

FIG. 10. Same case pulled together with transfixion screw. Plate applied pulling three fragments together, September 14, 1942.

FIG. 11. November 2, 1942, shows complete union in approximately six weeks. This patient was fifty-two years old.

FIG. 12.

FIG. 13.

FIG. 14.

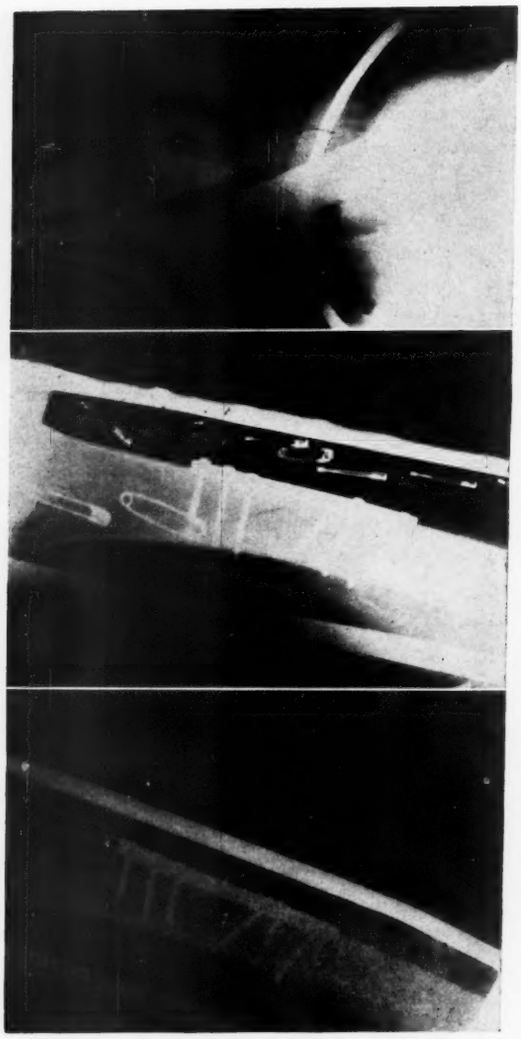

FIG. 12. Shows semi-oblique fracture, lower and middle thirds of femur in which upper fragment is fixed in adduction with flexion as result of tubercular hip in childhood.

FIG. 13. Transfixion screw is used to pull inverted v-shaped fragment into place. Plate applied over all, April 5, 1943.

FIG. 14. On July 16, 1943, same case shows perfect alignment and union maintained in this off center position. Knee function was maintained.

The interesting thing about the patient whose fracture is shown in Figures 12, 13 and 14 was that this man had a tubercular hip in childhood which became ankylosed in the usual posture of extreme

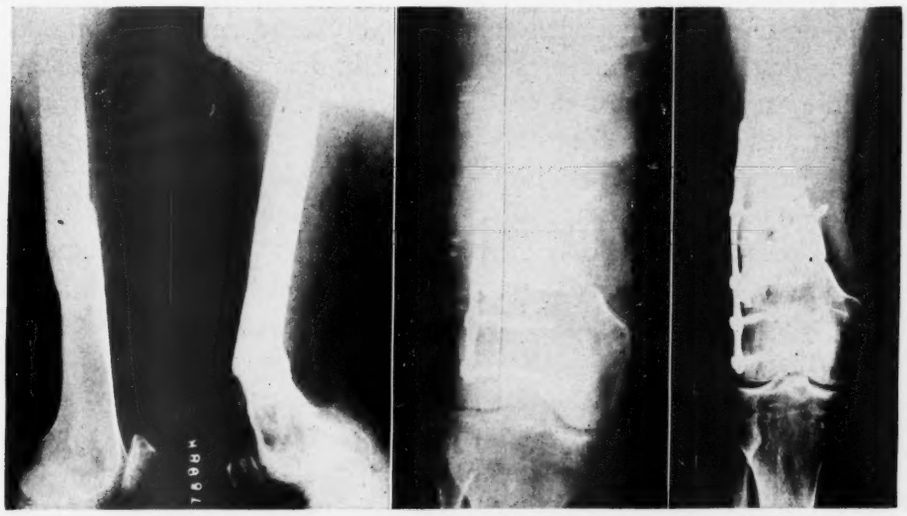

FIG. 15. FIG. 16. FIG. 17.

FIG. 15. Old fracture, lower third of the femur, united in extreme posterior angulation of lower fragment.

FIG. 16. Corrected position following osteotomy which is fixed by large transfixion screw and over all plate, June 23, 1942.

FIG. 17. Complete union in perfect position; weight bearing with perfect knee joint space as of August 14, 1942.

adduction with about 30 degrees of flexion. Figure 12 shows the first position of the upper fragment which had to be met at the time of the operation on April 8, 1943. It was very difficult to hold this position in counterbalance and at the same time maintain knee function. Figure 14 of August 10, 1943, shows early union and perfect position. This man was ambulatory in this extremely off-balanced posture and walking in October.

In Figures 15, 16 and 17 we have a case of osteotomy and repair for correction of a total disability of the knee due to united fracture in the lower third of the femur in angulation of about 30 degrees backward. Osteotomy was done, the position corrected and a very heavy transfixion screw (short hip screw) was used in addition to which a plate was added. Figure 15 shows the old fracture line and disability which was corrected on June 23, 1942. The next two skiagrams in anteroposterior and lateral views (Figs. 16 and 17) show union with weight bearing with complete knee function on October 14th.

I have attempted to show by this direct review of a principle, that as we have gone through the years in the discussion of fractures, we have come to recognize two factors: First, I and my associates announced some eight or nine years ago that there must be absolutely no chemical irritation from electrolytic action on any metal used in bones about fractures which would delay the healing of the fracture or would interfere with new bone growth. Second, I think we can and must do definitely what both we and our forefathers have tried to do throughout the years, which is to immobilize fractures completely. In some of the heavier, long bones it takes a transfixion screw or a bolt of some sort, transversely or obliquely through the fracture ends to prevent any motion up or down or back or forward, while adjacent joints are continued in function in counterbalance.

I believe if these two factors are kept before us and used with the simple thought in mind of complete immobilization and the complete absence of chemical irritation due to electrolysis, it can mean the difference of practically no delayed or non-unions, 20 to 30 per cent taken from the period of disability and a minimum of temporary or permanent limited function of adjacent joints, particularly of the dreaded stiff knee in fractures of the femur or of the limited shoulder or elbow function in fractures of the humerus.[4]

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Original Articles

THE USE OF LONGITUDINAL WIRES IN BONES IN THE TREATMENT OF FRACTURES AND DISLOCATIONS

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WHILE the original application of wires longitudinally in the medullary cavities of bones was applied to the clavicle,[1] the principle has been found to be very effective in many other regions. It seems to be effective and to simplify the treatment of some fractures in which the results of orthodox methods are not altogether satisfactory and in which the Stader and Roger Anderson methods of treatment are least effective. In long bones with large medullary cavities such as the tibia and femur, the wire is of such small caliber that it allows too much lateral displacement of the fragments, and especially in oblique fractures of these bones it allows too much shortening to be the method of choice. However, in the clavicle, scapula, both bones of the forearm, some cases of fracture of the humerus and long bones of the hands and feet, it provides a method by which greatly improved results in these fractures can be expected. Acromio and coracoclavicular[2] dislocations are easily controlled by this method. Naturally, as in all procedures in which it is necessary to make an opening in the skin, the most rigid aseptic surgical technic must be observed. In our hands there has been one infection only in which it was necessary to remove the wire on this account.

It would seem that the anatomy of the skeleton was arranged so that these wires could be applied with great ease, to the areas in which they are most effective. In the humerus the wire is passed through the greater tuberosity, and vertically down the shaft the wire is placed in an extra-articular position. Passed in this way it gives excellent control of fractures of the high surgical neck or shaft. With such a wire in position the arm has been carried in a sling only,

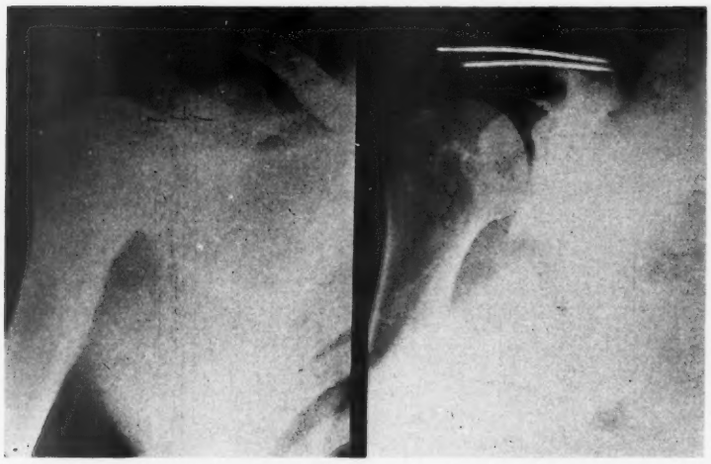

FIG. 1. Fracture dislocation of the surgical neck of the scapula and acromioclavicular joint; closed reduction; wire across joint gave excellent reduction and fixation.

FIG. 2. Fracture of middle finger metacarpal; fixation with wire.

FIG. 3. Fracture through neck of proximal phalanx of great toe, with 90 per cent plantar rotation; open reduction and fixation with longitudinal wire.

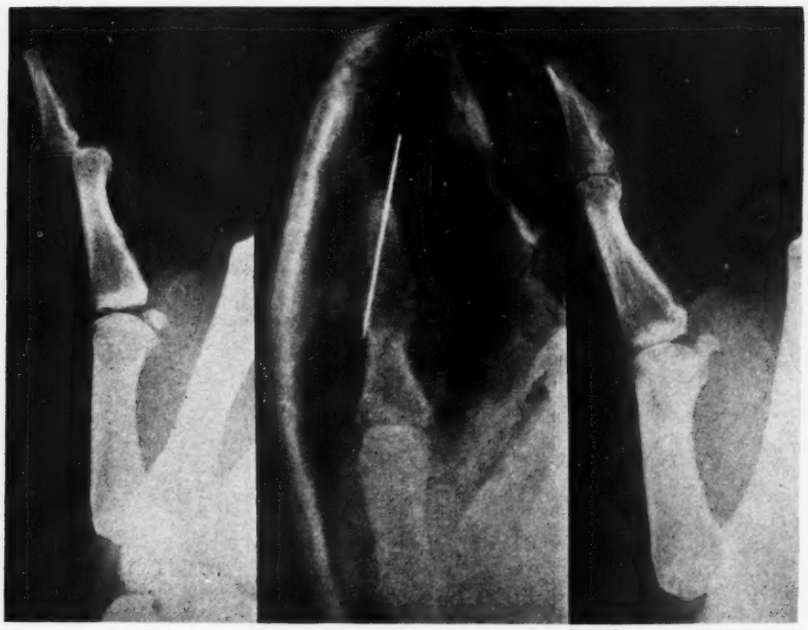

FIG. 4. Dislocation of interphalangeal joint of thumb of three months' duration; maintained in place by wire.

and excellent union in a good position has resulted. In the forearm with fractures of both bones, the subcutaneous olecranon, provides a very easy approach, through which to pass the wire through the

FIG. 5. Fracture index metacarpal; fixation with longitudinal wire following open reduction.

proximal and into the distal fragment. In the radius, the subcutaneous styloid process offers an easy and extra-articular approach, passing the wire through the distal and into the proximal fragment. If after reduction and fixation of the ulna with the wire, the radius can be reduced, it also is held by passing a wire. If, however, the fragments are so engaged that closed reduction is impossible, a short incision over each bone should be made and accurate reduction obtained. The wires then passed as described, provide excellent fixation which is quite easy to apply. To date, all such fractures have been fixed in plaster casts until evidence of union has taken place. In the metacarpals and phalanges, when reduction has been obtained, the wire can be passed, in the case of the metacarpal, through the distal articular end, crossing the fracture line into the proximal fragment, with the proximal phalanx flexed to an angle of about forty-five degrees. If the fracture is at the neck or near the head of the metacarpal, the wire is best passed through the distal articular end of the proximal phalanx, through its medullary cavity, crossing the metacarpophalangeal joint, through the distal fragment and well into the proximal. In fractures of the phalanges, after reduction,

the wire is passed either through the distal articular end of the affected phalanx or through the tip of the finger and across the interphalangeal joint, if necessary. In none of these fractures has

FIG. 6. Coxa vara; cuneiform osteotomy (Gants'); fixation with longitudinal wires; plaster cast.

there been evidence of any ill effect in the way of discomfort or disability as a result of a fine wire traversing the articular cartilages.

In fractures of metacarpals, the method of transverse fixation by Kirschner wire as described in an article by Norman[3] also gives excellent results.

Use of wires in a similar way offers excellent fixation in arthrodesis of interphalangeal or metacarpophalangeal joints in the hand or foot.

There is no doubt that this form of fixation, as described by the author,[1] is the most satisfactory from all points of view in fractures of the clavicle. In dislocations of the acromioclavicular joint, fixation by two or more wires gives a most satisfactory result with no permanent deformity. With acromioclavicular and wide coracoclavicular[2] separation, fixation of the acromioclavicular joint by wires also provides a very easy and effective method of allowing repair of the coracoclavicular ligaments with subsequent excellent stability and function of the shoulder girdle.

In fractures of the surgical neck of the scapula with gross deformity and projection of the axillary border of the scapula into the axilla, the best treatment is by an open reduction. A longitudinal

FIG. 7. High shaft fracture of humerus with eighty degrees of angulation; fixation by Kirschner wire.

wire through the heavy axillary border of the scapula and up into the glenoid fragment provides excellent fixation, which is difficult to obtain and apply otherwise.

Longitudinal wires also provide an easy and excellent method of fixation of internal and external malleolar fractures at the ankle when closed methods of reduction are not satisfactory.

When an osteotomy of a long bone to correct alignment or rotary deformity is about to be done, the question of the best method of fixation of the artificial fracture arises. In Gant's subtrochanteric osteotomy to correct adduction deformity, the lower fragment tends to be displaced medially when the femur is divided across, even though oblique or semicircular incisions are made across the bone. The procedure is greatly facilitated and the fixation is adequate when a longitudinal wire is passed through the tip of the great trochanter and down the shaft of the femur. When the base of the wedge or cuneiform osteotomy has been removed, the medullary

cavity is exposed and the position of the wire can be verified. The fracture is then completed and without fear of displacement the

FIG. 8. Fracture of anatomical neck of humerus with dislocation of the head; fixation by longitudinal wire.

FIG. 9. Comminuted fracture of both bones of forearm; satisfactory result by wire fixation.

lower fragment of the femur can be abducted or rotated at will to correct the deformity. No further internal fixation of the fracture is required. Of course the usual external plaster cast is necessary to

maintain the corrected position. Similar principles can be applied in other areas.

A series of illustrative cases is reported and the *x*-rays demon-

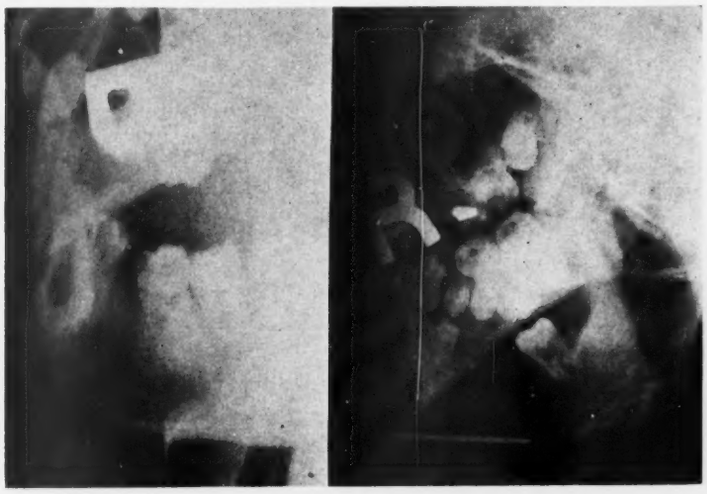

FIG. 10. Fracture of jaw (symphysis); fixation by longitudinal wire.

strate the use of the wires and the end results obtained. In all there have been 154 patients treated with longitudinal wires. There was one case of infection in which a wire was applied longitudinally in the humerus for a fracture of the surgical neck. In this case the wire had been used by an inexperienced house officer, which may have been a factor in the subsequent infection. In none of the clavicle or acromioclavicular joints has there been any injury to the brachial plexus or axillary or subclavian vessels. None of the wires has drifted out of the field. From my experience in more than one hundred clavicles and acromioclavicular joints, if the wire is placed where it is intended to be, it will not migrate.

The presence of the wire across the fracture line has not impeded the rate of union of the fracture and there have been no non-unions in this series. On the contrary, in most cases these fractures have united in a shorter time than ordinarily would have been expected.

CONCLUSIONS

1. Longitudinal wires in bones have provided excellent fixation of certain selected fractures and in particular those fractures in which it has been difficult to obtain satisfactory fixation by external splinting either with or without skeletal pins.

2. There has been no evidence that a small or medium sized Kirschner wire which traverses articular cartilage produces any deletory effect on the joint.

3. When wires are applied under good surgical conditions and divided to lie beneath the skin, there should be very little chance of infection resulting from their use. (One case in our series.)

4. When the wires are placed in bones, even though they cross joints, there has been no evidence of migration of the wires in this series of cases.

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DISCUSSION

Lieut. Col. Martillus Todd (Norfolk, Va.): In the first place I want to congratulate Dr. Murray for his very ingenious use of these wires. I think we are all familiar with the principle of using the wire, but I do not believe most of us have gone to as much trouble in developing this as he has.

It seems to me that his results in the fractured forearm particularly speak for themselves. It is a very difficult fracture to treat. I do not know how much trouble he has getting those wires in place. I suppose it is done with the fluoroscope, but in any case when he has done it, the fracture evidently cannot get out of place, and it appears to be a method of treatment that is very well worth using.

I want to call attention to one difference. Of course, there are a number of differences in the case of fractured bones in the armed services. In civilian life if a man breaks his collarbone it is of no particular importance because by any method of treatment, even though he has a big lump of bone afterward with overlapping, some shortening, some deformity or angulation, it is not of any particular consequence to a civilian. He simply has a lump on his shoulder, but his arm is very strong and he is able to carry on without any trouble.

Soldiers cannot do that. They have to wear a heavy pack, and the straps go right across the middle of the clavicle where the break is apt to be. We have had to classify for limited assignment a good number of soldiers who came to us after having broken their collarbones in civilian

life, after having been able to do their civilian work without any trouble at all. But as soldiers they are not able to wear the heavy pack; sometimes their shoulders are not strong enough to enable them to go over the obstacle course either.

If these wires can be used without incision, it is better to avoid a scar anywhere near a spot where anything could rub on it.

So I suppose the subcutaneous method of putting the wires in is preferable. There are many other comments that could be made; one is the matter of infection. Dr. Murray has had only one infection in 154 cases, which may be due to inaccurate technic on the part of a house officer. Unfortunately, I have had an infection or two myself in doing open work on bones.

I remember one particularly distressing case which had an infection in the shaft of the metacarpal bone of the ring finger, and it stiffened the metacarpophalangeal joint, so that the patient could not make a good round fist.

Those fractures also, I think, are quite difficult to treat, and if Dr. Murray is able to treat them as successfully as his *x*-rays indicate, I think it is a method that deserves our congratulations.

KELLOGG SPEED: Mr. President, members and guests: This device I have known for several years and have seen Dr. Murray use it. I have also used it successfully in the acromioclavicular, finger and metacarpal bones. I wish, however, to report very briefly one case, hoping that no others of you may have the unfortunate experience which I had.

A young boy with a sternoclavicular dislocation, which could not be held by ordinary means, was subjected to this procedure. It was done under general anesthesia. The Kirschner wire drill was rather cumbersome and heavy, and just as I was inserting the wire through the inner end of the clavicle into the sternum, the boy gave several convulsive coughs and jerked his body as he lay on the table. My wire was forcibly projected into the thoracic cavity and the aorta was punctured. A slow leak occurred down inside the reflexion of the pericardium. Within ten hours a heart tamponade developed and the boy passed away during my absence from the hospital.

In operating on the sternoclavicular joints or those near the great vessels, I think we should be very sure about the rigidity and quiet of the patient, and the presence of completely relaxing anesthesia.

RICHEY L. WAUGH (Boston, Mass.): In support of this treatment I should like to show a few slides which will speak for themselves. These slides cover some fractures other than the ones Dr. Murray showed. (Dr. Waugh then produced the following slides):

1. A malunion of the fifth metatarsal with about 40 degrees angulation. In this the longitudinal wire was passed up the shaft.

2. Malunion of the fifth metatarsal and non-union of the fourth and third metatarsals. This showed the marked displacement and angulation.

3. Longitudinal wires passed up the shafts.

4. In this slide a dislocation of the proximal end of the first metacarpal was shown. This was reduced by open operation and a Kirschner wire used for fixation.

5. This was a compound comminuted fracture in a patient who was admitted to the hospital about three weeks after the injury, with a large open wound, and the distal end of the tibia and the internal malleolus sloughed out. The defect was shown. The end of the tibia was approximated to the astragalus with overriding o the fibular fragments, and as the wound closed in a thin osteotome was taken and the end of the tibia and top of the astragalus were squared off, bringing these together.

Two longitudinal pins were passed up, not wires, through the calcis, the astragalus and the tibia. The final result was fusion between the astragalus and the distal end of the tibia. The foot was put up in slight equinus position and the boy is walking with a special shoe at the present time.

6. In this case we see not a simple Monteggia fracture but a rather complicated one. There were five fragments. The fragments were in a duck-bill arrangement. This patient was treated by open operation, not using a wire but a pin. The pin was inserted through the proximal fragment and then through the distal fragment, and the minor fragments were assembled around the pin and held by a circumferential wire.

GROVER WEIL (Pittsburgh, Pa.): We have found Dr. Murray's method very applicable in displaced fractures in the lower end of the radius and the ulna. Instead of using the wire we use a threepenny nail. After reposition of the displaced fragment we insert the nail into the distal end of the fragment, and the protruding end rests upon the distal fragment, holding it in very excellent position. It can be easily discarded after union is obtained. This is done with a threepenny nail instead of the wire.

FRASER B. GURD (Montreal, Canada): (Dr. Gurd showed a number of slides that were self-explanatory):

1. Monteggia Fracture—In this fracture of the ulna the wire was placed into the upper fragment, then pushed all the way out so its blunt end would run into the distal fragment; it was then pushed in by hand. That seemed to do the trick. At the end of five months there was a synostosis. The removal of the head of the radius had been deferred until this time, and a month or so ago the head and neck of the radius were removed, the synostosis was divided and removed, and the result is now fairly satisfactory.

2. This was a fresh Monteggia, which was treated in exactly the same way. It is still under treatment, and it seems as though it is holding and in a satisfactory position.

3. This showed the use of a short wire which is put in through a compound injury in just the way in which Dr. Murray suggested.

4. This was an illustration of a non-union of several years' duration, in which plating had been employed; the screw holes were seen, with the fracture. The wire was placed in through the medullary cavity up and down, and then a period between operation and apposition of the bones was allowed to lapse, about two weeks, at which time the sutures were taken out and then—and then only—were the bone ends jammed together. Although it was a four-year non-union prior to operation, union was firm and function of the limb was being recovered reasonably well within six months.

5. This was a subtrochanteric fracture of the trochanter with non-union at the end of six months. It showed the use of multiple wires following correction, similar to the way in which Dr. Murray suggested.

I should like to make one comment with regard to Dr. Murray's reference to the acromioclavicular joint, and Dr. Speed's reference to the sternoclavicular dislocation.

I urge again, as I have done before, that a method which is associated with any risk whatever should not be employed, but that in the case of the acromioclavicular the outer third of the clavicle should be removed, and in all cases in which dislocation of the sternoclavicular joint requires any interference, that interference should be removal of the medial third or half of the clavicle. I believe the results are much more satisfactory.

JOHN A. CALDWELL (Cincinnati, Ohio): Will Dr. Murray give his method of hand protection against the *x*-rays in this procedure?

GORDON MURRAY (closing): I should like to thank the discussers for their comments and further elaboration of the principle mentioned here.

Regarding the question of the fluoroscope, I do not work under the fluoroscope. Many of these things are done at open reduction, and the procedure is carried on according to anatomical detail. If we do use the fluoroscope, we take just a peep to see what has happened after we have done something. We do not work continuously under it. I get my hands out of the field after we have done something and see if it is all right. If it is not, we shut off the screen and do it over again and take another look.

I should like to make one further comment: Regarding the question of migration of wires, there have been some publications indicating that wires have gotten into pleural cavities and other obscene places. It is my experience that if a wire is placed where it is intended to be, it will not migrate, and in none of these cases has it changed its position in the least.

I would suggest, if it is in the pleural cavity, that somebody put it there. It did not go there by its own intelligence or otherwise.

PHANTOM LIMB PAIN*

ITS RELATION TO THE TREATMENT OF LARGE NERVES AT TIME OF AMPUTATION

LOUIS G. HERRMANN, M.D. AND EDWARD W. GIBBS, M.D.
CINCINNATI, OHIO

THE clinical syndromes of phantom limb pain and causalgia which may follow the amputation of an extremity should be given serious consideration in this time of war since the victims of these complications are certain to present a major problem for therapy and reconstruction in the years which lie ahead. Recently, Commander James C. White[1] presented an excellent review of the problem of pain after amputation of an extremity and outlined the accepted methods of treatment, yet he was careful to emphasize the fact that there is no single method of treatment which is uniformly successful in eradicating such pain. He wisely added the caution that one must always bear in mind that an ineffectual or mutilating surgical procedure which is performed in the treatment of these difficult problems usually adds another psychic trauma which will eventually result in further suffering and loss of morale.

The phenomenon of the phantom limb sensations has puzzled neurologists, psychiatrists, and surgeons ever since Mitchell, Morehouse and Keen[2] presented the results of their experiences with gunshot wounds and other injuries of nerves during the Civil War. Very little new information has been added to the clinical aspects of the syndrome since that time. As a result of the present war, the nature and probable causes of the symptoms are being studied with renewed interest by neurophysiologists, psychiatrists, and surgeons with the hope of reducing the suffering from this dreaded complication which may follow severe injury to an extremity.

Most patients are conscious of their absent extremity after amputation. This phantom limb sensation may be present only for a brief period and usually it is not painful. Phantom limb sensation of this variety usually disappears after the patient begins to wear an artificial extremity.

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In some patients, however, these sensations may take the form of severe burning or boring pain and the victims may even complain that the distal parts of the extremity are being constricted or compressed. They may also complain that a specific pain which was present in the fingers or toes before amputation persists unchanged in the phantom limb. Because of the great variation in the intensity of phantom limb sensations and the location or character of the pain, these patients usually do not receive serious consideration and the surgeon frequently assumes that they suffer from some form of psychoneurosis.

In favor of a central origin of these sensations, particularly that the symptoms might represent an obsession neurosis, are the observations that no peripheral end organs can account for the sensory impressions of posture, touch, and movement. The patient usually feels most vividly the parts of the limb which have the greatest representation in the cerebral cortex, especially the hand, index finger, toes and foot. Most patients report the phantom limb to be frozen in one position, a position which corresponds to that position in which the injured limb was last seen by the patient. Nervousness and emotional instability, which may be evident by the time the patient comes under observation in his quest for relief of pain, are thought to indicate a temperament which favors the development of an obsession neurosis.

From a clinical standpoint no one could object to any of these observations, but when they are used to exclude the possibility that peripheral irritation can be playing a part in the causation of the phantom limb pain and to prove the pure psychic origin of this condition, we must agree with Livingston[3] that the evidence is inconclusive. Our own observations support Livingston's contention that peripheral irritation, while by no means constituting the whole story, *does* represent an important factor in the syndrome of phantom limb pain. We do not believe that the symptoms are purely psychic in origin.

Bailey and Moersch[4] made a study of 105 patients who had had an extremity removed and they concluded that the symptoms in their patients could not be ascribed to peripheral irritation alone. They state that the mechanism of the pain was not clear and on the basis of their study they hesitated to accept the theory of ascending neuritis or peripheral irritation, *but they make no mention of how the large nerves were treated at the time of amputation*. They concluded, on

clinical grounds alone, that the symptoms were of central origin and stated that the evidence in their cases suggested the possibility that the phenomenon represents some form of obsession neurosis.

This interpretation of the phantom limb sensations and pain seems to represent the opinion of the majority of the students of this phenomenon. It is usually emphasized by these workers that if the syndrome came as a result of peripheral irritation, the excision of the neuroma or a re-amputation should cause the symptoms to disappear. It is the experience of most surgeons that such operative procedures usually fail to give lasting relief. Recent studies, however, seem to indicate that abnormal reflexes from the periphery to the higher centers of the central nervous system tend to become fixed or irreversible within a short time after extensive trauma to an extremity and that the subsequent removal of the original site of irritation does not always completely abolish these abnormal reflexes. The original idea of Mitchell, Morehouse and Keen[2] that an ascending neuritis was responsible for the pain has never been proved by histologic studies of the large nerves removed during therapeutic neurectomies (White).

INCIDENCE OF PHANTOM LIMB SENSATIONS

It is extremely difficult to ascertain accurately the incidence of phantom limb sensations or pain after amputation of an extremity. According to Leriche,[5] the syndrome is present in about 98 per cent of patients who have had an amputation of an extremity. Wier Mitchell[6] based his study upon ninety patients who had had an extremity removed: eighty-six of these patients experienced phantom limb sensations and fourteen had severe pain or causalgia. This represents an incidence of 95 per cent for phantom limb sensations and at least 15 per cent incidence of phantom limb pain. Bailey and Moersch[4] followed fifty patients who had had an extremity amputated at the Mayo Clinic and forty-three of these patients complained of phantom limb sensations or pain. This represents an incidence of 86 per cent. Our study deals only with *phantom limb pain*. Severe trauma and extensive arterial occlusion due to primary or secondary arterial thrombosis gives the greatest incidence of phantom limb pain (20 to 25 per cent) (Table 1). The average incidence of *phantom limb pain* in our series of 120 patients who survived amputation of an extremity and who were followed for an adequate period of time was only 5.8 per cent. (Table 1.)

PREVENTION OF PHANTOM LIMB PAIN

Stimulation of the afferent pathways of large nerve trunks which have been divided certainly provokes abnormal reflexes in the spinal

LIGATION OF MAJOR NERVE TRUNKS AT TIME OF AMPUTATION
JANUARY 1937 TO JANUARY 1944

			INCIDENCE OF PHANTOM LIMB PAIN		
DISEASE	NUMBER OF PATIENTS SURVIVING AMPUTATION	NUMBER OF PATIENTS WITH ADEQUATE FOLLOW-UP STUDIES	NUMBER OF PATIENTS WITHOUT PHANTOM LIMB PAIN	NUMBER OF PATIENTS WITH PHANTOM LIMB PAIN	INCIDENCE OF PHANTOM LIMB PAIN
ARTERIOSCLEROSIS OBLITERANS WITH DIABETES MELLITUS	85	61	59	2	3.3%
ARTERIOSCLEROSIS OBLITERANS WITHOUT DIABETES MELLITUS	67	41	38	3	7.3%
INFECTION	4	2	2	0	0
EMBOLISM OR THROMBOSIS	5	5	4	1	20.0%
TRAUMA	4	4	3	1	25.0%
NEOPLASM	6	5	5	0	0
THROMBOANGIITIS OBLITERANS	4	2	2	0	0
TOTAL	175	120	113	7	5.8%

TABLE 1. The incidence of phantom limb pain following amputation for various diseases.

cord and Riddoch[7] believes that the processes of healing of the proximal end of the divided nerves evoke sensations which are projected and interpreted as if the limb were still present. He states that "during the stabilizing process of healing of the divided nerves, the sensory impulses dimniish, and the sensations become correspondingly fainter with the result that the phantom limb is increasingly less obvious in outline and projection; consequently it gradually approaches the stump into which it finally disappears and fades away. If, however, the phantom limb is painful, which is usually the result of grossly abnormal conditions in the stump, the phantom may persist indefinitely and retain its original position."

We are of the opinion that the most probable primary cause of the phantom limb sensations or pain is irritation of centrally conducting axones within a neuroma or at the proximal end of a freshly cut mixed nerve. These axones formerly brought impulses to the higher centers from the part which has been removed. It is not necessary for such irritation to persist since the abnormal reflexes within the spinal cord which it provokes may cause the sensations or pain to continue even after all known afferent pathways from the extremity have been severed.

We began this study seven years ago with the primary object of preventing the irritation of afferent pathways in the mixed nerves of the extremity at the time of amputation and during the immediate postoperative period by preventing abnormal scar tissue formation or the formation of neuromas at the site of division of the large nerve trunks. It is generally agreed that the simple formation of a neuroma on a large nerve is in itself not always provocative of painful sensations. All patients with phantom limb pain upon whom we have performed secondary operations on the stump, or when we have had the occasion to study the nerves at autopsy, have shown either abnormal scar tissue formation about the nerve, neuroma formation on the proximal end of the cut nerve, or local inflammatory changes about the end of the large nerve trunks. The irritability of the neuroma, or, perhaps as Boldrey[8] has recently suggested, the *size* of the neuroma might account for the difference in reaction in the absence of abnormal scar tissue formation or inflammatory changes. The fact that Livingston[3] has observed several individuals with multiple amputations in whom only a single stump became painful tends to refute the idea that these patients are unduly sensitive to pain.

TREATMENT OF LARGE NERVES DURING AMPUTATION

There seems to be no unanimity of opinion regarding the treatment of large mixed nerves at the time of amputation but the mere fact that more than a score of methods are now being used throughout the world suggests that no single method has proved entirely successful. We believe that insufficient thought has been given to this aspect of the problem.

Boldrey[8] recently revived interest in this phase of the problem and presented his own method of preventing the formation of large neuromas on the ends of major nerve trunks by inserting the end of the cut nerve into the adjacent bone. His excellent summary of the other methods for treating the nerves at the time of amputation will be used here in order to conserve time and space.

"Probably the oldest preventive method, one still commonly recommended, consists of pulling down the nerve as far as it will conveniently stretch, cutting it with a sharp scalpel and allowing the proximal end to retract into the areolar tissue well above the end of the stump. Bardenheuer (1908) modified this method by turning the cut end of the nerve back and implanting it beneath the sheath of

the same nerve higher up, forming a loop. Krueger (1916) merely crushed the nerve in forceps. Sicard (1916) felt that sensory fibers only would be destroyed by 60% alcohol and recommended its use.

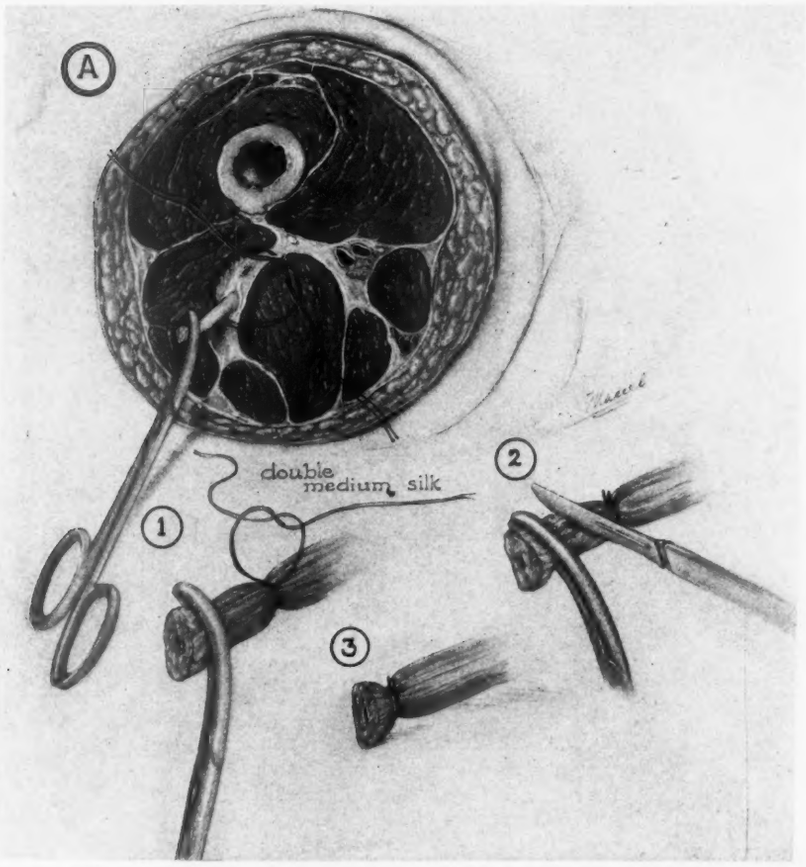

FIG. 1. The method of ligating large nerve trunks with non-absorbable suture material at the time of amputation.

Chapple (1917) turned back an epineurial cuff several millimeters in width, cut off the neuraxes and pulled down the cuff, tying it below the cut ends. Moscowicz (1918) inserted the end of the nerve into muscle. Corner (1918) excised an inverted wedge to form a 'swinging door flap,' the edges of which were sutured together. Hedri (1920) used the cautery to seal the end of the nerve and prevent the irritating effect of secretions from the wound. Huber and Lewis (1920) tied off the nerve and injected about one cubic centimeter of absolute alcohol from one to three centimeters above the site of the ligature. Stookey (1922) recommended a combination of Corner's swinging

door flap and the injection of absolute alcohol. Laewen (1925) used refrigeration. Foerster (1927) injected 5% formalin into the central stump. Beswerschenko (1929) recommended Federoff's method of

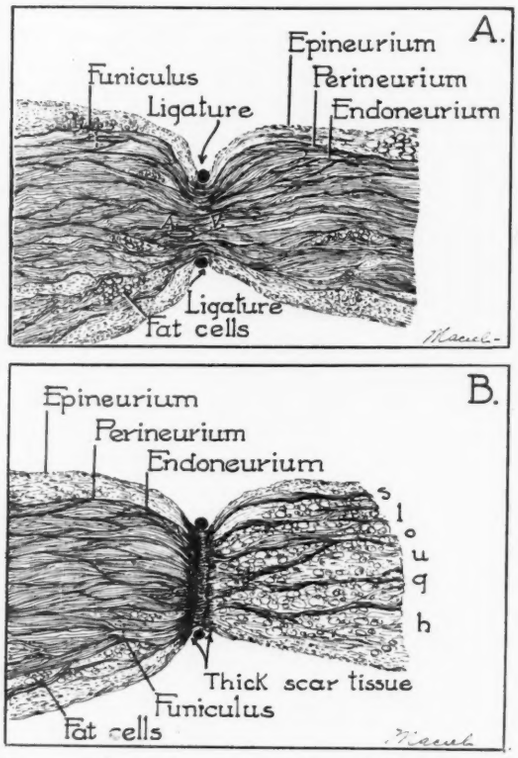

FIG. 2. Schematic representation of the effect of the non-absorbable ligature about a large nerve. A, the immediate effect of the ligature; B, the effect after one month.

phenolization of the end of the nerve and the injection of liquid phenol into the stump above the cut end. Lexer (1931) tried electrocoagulation."

In this review, however, Boldrey[8] made no comment as to the relative success of these various methods in the prevention of post-operative pain or phantom limb sensations. He simply makes the statement that the value of his own method of implanting the cut end of the nerve into the bone for the prevention of painful amputation neuromas cannot be stated at this time.

Our study centers around the simplest and most physiologic method of preventing regeneration of axones from the cut end of a large nerve by placing a non-absorbable ligature tightly around the uninjured nerve trunk about an inch above the site of amputation.

(Fig. 1.) Such a ligature will always control the bleeding from the nutrient artery of the large nerve and it causes a narrow line of pressure necrosis of the nerve tissues immediately beneath the ligature.

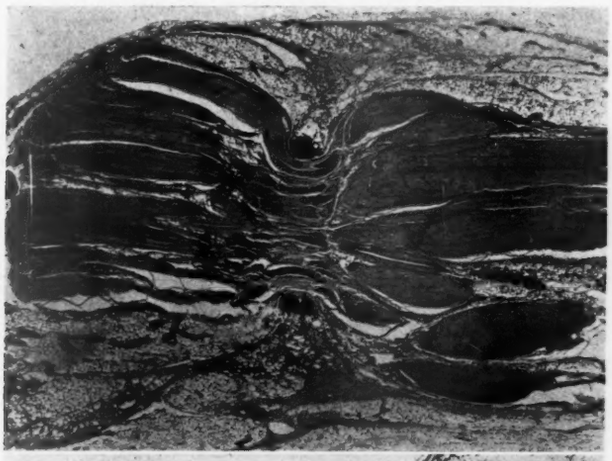

FIG. 3.

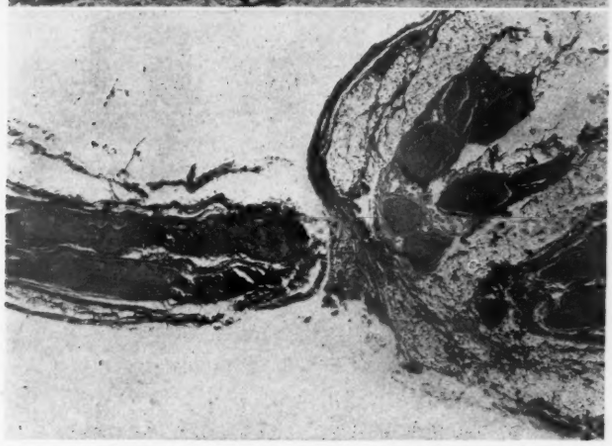

FIG. 4.

FIG. 3. Microphotograph of the sciatic nerve of a man. Specimen removed six days after a non-absorbable ligature had been placed around the nerve at the time of amputation. Note area of pressure necrosis immediately beneath the ligature.

FIG. 4. Microphotograph of the sciatic nerve of a man. Specimen removed one month after a non-absorbable ligature had been placed around the nerve at the time of amputation. Van Giesen stain showed that the epineurium was continuous with the scar tissue at the end of the nerve and no neuromas were present.

(Fig. 2A.) The regeneration of axones is prevented by the occlusion of the neurilemma sheathes: first, by the ligature itself and later, by the ingrowth of fibrous tissue (Fig. 2B.) Histologic studies made upon large nerves treated in this manner show a gradual replace-

ment of the area of pressure necrosis by fibrous tissue (Fig. 3) until finally, after about one month, the epineurium completely encases the end of the nerve except for a small area of dense fibrous tissue at the extreme end. (Fig. 4.)

LIGATION OF MAJOR NERVE TRUNKS AT TIME OF AMPUTATION
JANUARY 1937 TO JANUARY 1944
SUMMARY OF CLINICAL DATA

DISEASE	TOTAL NUMBER	SEX		AGE DISTRIBUTION					END RESULT		
		M	F	UNDER 40	40-49	50-59	60-69	OVER 69	RECOVERED	DIED	OPERATIVE MORTALITY
ARTERIOSCLEROSIS OBLITERANS WITH DIABETES MELLITUS	110	64	46	1	4	22	45	38	85	25	22.7%
ARTERIOSCLEROSIS OBLITERANS WITHOUT DIABETES MELLITUS	88	63	25	0	3	12	25	48	67	21	23.9%
INFECTION	12	10	2	3	2	3	0	4	4	8	66.7%
EMBOLISM OR THROMBOSIS	14	8	6	1	4	1	2	6	5	9	64.3%
TRAUMA	4	4	0	1	1	0	2	0	4	0	0
NEOPLASM	6	5	1	2	0	2	2	0	6	0	0
THROMBOANGIITIS OBLITERANS	4	4	0	2	2	0	0	0	4	0	0
TOTAL	238	158	80	10	16	40	76	96	175	63	26.5%

TABLE II. Summary of clinical data.

This problem of the healing of large nerves after various methods of treatment has been studied in our laboratories by Schnug.[9] He found that if the large nerve was crushed before the non-absorbable ligature was applied, the neurilemma sheathes were invariably ruptured and neuromas developed in spite of the ligature. Ligatures of absorbable material were found to loosen or disintegrate before complete healing of the end of the nerve had taken place and it was his conclusion that such material should not be used to ligate large nerves at the time of amputation.

ANALYSIS OF CLINICAL DATA

During the seven years from January, 1937, to January, 1944, we performed 238 major amputations at the Cincinnati General Hospital and the Christian R. Holmes Hospital of the University of Cincinnati. The large nerve trunks were simply ligated with non-absorbable material at a point about one inch above the site of amputation in all of these patients. The nerves were never crushed before the ligature was applied. Of these patients 150 were males and eighty were females. The operative mortality for the entire series of

238 patients was only 26.5 per cent although a much higher operative mortality resulted among those patients with spreading cellulitis and infectious gangrene (66.7 per cent) and those with extensive arterial thrombosis superimposed upon obliterative arterial disease (64.3 per cent). The detailed analysis of these data with reference to the disease, sex, age distribution and end results is given in Table II.

LIGATION OF MAJOR NERVE TRUNKS AT TIME OF AMPUTATION

JANUARY 1937 TO JANUARY 1944

NATURE OF PHANTOM LIMB PAIN					
INITIALS AND NUMBER	AGE	SEX	DISEASE	PHANTOM LIMB PAIN	
				DURATION	CHARACTER
G.M. - C.G.H. 184262	76	M	GANGRENE OF RIGHT ARM DUE TO THROMBO-EMBOLISM OF RIGHT BRACHIAL ARTERY	8 MONTHS	PARESTHESIA WITHOUT SEVERE STUMP PAIN
G. C. - C.G.H. 152904	79	M	ARTERIOSCLEROSIS OBLITERANS WITH DIABETES MELLITUS	8 MONTHS	PAIN IN TOES SIMILAR TO PRE-OPERATIVE PAIN-NOT SEVERE.
N. L. - C.G.H. 176457	74	M	ARTERIOSCLEROSIS OBLITERANS WITHOUT DIABETES MELLITUS	2 MONTHS	PAIN IN TOES PARESTHESIA IN PHANTOM FOOT.
R.W. - C.G.H. 152139	61	M	ARTERIOSCLEROSIS OBLITERANS WITHOUT DIABETES MELLITUS	2 MONTHS	SEVERE SHOOTING PAINS IN PHANTOM FOOT
W. S. - C.G.H. 164613	64	M	ARTERIOSCLEROSIS OBLITERANS WITH DIABETES MELLITUS	2 YEARS	SHARP PAIN. OCCASSIONAL MILD PAIN IN PHANTOM TOES
F. C. - H.H 380333	69	M	ARTERIOSCLEROSIS OBLITERANS WITHOUT DIABETES MELLITUS	6 YEARS	PARESTHESIA. SHOOTING PAINS IN PHANTOM FOOT. MUSCULAR TWITCHING IN STUMP
D. J. - H.H. 430377	42	M	TRAUMA (SUPRACONDYLAR FRACTURE OF FEMUR WITH THROMBOSIS OF POPLITEAL ARTERY FOLLOWING MALPLACING OF SCREW-PIN)	1 YEAR	PARESTHESIA. THROBBING PAINS IN STUMP. OCCASSIONAL PAIN IN PHANTOM TOES

TABLE III. Nature of phantom limb pain.

Of the 175 patients who survived the amputation of an extremity only 120 of them were followed carefully and long enough to permit evaluation of their symptoms after the operation. Of the 120 patients who had the large nerves ligated with non-absorbable material at the time of operation, 113 stated that they had never experienced phantom limb pain after the operation. Only seven patients (5.8 per cent) of the group which had been adequately studied complained of phantom limb pain. (Table III.) This represents a very low incidence of phantom limb pain in such a series of patients which includes all forms of infectious gangrene and arterial disease as the precipitating cause for the loss of the extremity.

When we analyze more carefully the seven patients of this series who complained of phantom limb pain, we find that all but one of the patients were in the sixth or seventh decades of life. All were males and five of the seven patients had gangrene due to arterial insufficiency while two had extensive arterial thrombosis in the extremity. In all seven of these patients the pain was severe enough to be disabling but in none of the patients was the pain intolerable.

CONCLUSIONS

Irritation of centrally conducting axones by neuromas, local inflammatory changes, or by abnormal scar tissue formation about the end of the nerves may give rise to intractable pain in the phantom limb following amputation.

Placing a tight ligature about the *uninjured* large nerve trunk at a point about one inch above the level of amputation constitutes a simple and physiologic method of preventing the regeneration of axones from the cut end of the nerve.

The incidence of *phantom limb pain* in this series of 120 patients who were adequately studied after a major amputation of an extremity was highest (25 per cent) for the four patients with severely traumatized limbs but only 5.8 per cent for the entire group.

The analysis of the clinical data presented in this study indicates that the treatment of the large nerves at the time of amputation is of considerable importance in preventing the occurrence of phantom limb pain.

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DISCUSSION

John Caldwell (Cincinnati, Ohio): The whole question of phantom limb pain and painful stump has been an embarrassing complication to every surgeon who occasionally has had to do an amputation.

Most of us have been particularly disappointed after the resection of ancient neuroma that are painful. The person who has had a painful stump for a number of years, in a large proportion of patients, is a drug addict, and between periods of addiction he is usually subjected to another neurectomy.

Consequently, any attempt to prevent these sequelae is one of the most useful and constructive problems in surgery. The explanation, as Dr. Herrmann has indicated by his complete digest of the literature from that fountainhead of peripheral nerve surgery, Mitchell, Morehouse and Keen, down to the more recent studies, has shown that it is far from a solved problem.

There seems to be a certain amount of justice in the hypothesis that after this has persisted for a time, the persistence of the pain represents a central resentment to the peripheral lesion.

I might call your attention to an analogy that is worth probably a little more than the ordinary analogy in these cases, and that is with postherpetic neuralgia, which in many ways is similar, just as persistent and just as unexplainable.

Postherpetic neuralgia is a persistent thing and does not react to any treatment, resection of the nerve and resection of spinal cord tracts are all futile for giving any relief. That has been the case with these phantom limb pains and with painful neuroma.

Consequently, this plan of prevention which has been suggested, unlike the others, has been checked to a certain extent by fairly convincing histologic studies, and is worthy of considerable interest.

ARTHUR R. METZ (Chicago, Ill.): Surgeon General Kirk, in a recent monograph on Amputations, describes the various ways of treating the nerves and concludes as follows: "There is no ideal method."

He describes the technic of Huber and Lewis which he uses. The method consists in retracting the muscle, pulling down on the nerve, and under tension, tying with plain catgut close to the muscle to control hemorrhage, and retaining the absolute alcohol which is injected with a small needle. The nerve is then severed below the ligature with a sharp knife, and retracts upward in the undisturbed intermuscular septum. Huber and Lewis showed experimentally in animals that when the nerve end is injected with absolute alcohol, the axis cylinders are killed and neuromas do not form.

In our own work, we ligate large nerves with chromic gut to control bleeding and sever the nerve with a quick oblique cut with a sharp knife. Years ago we used to inject the nerve with alcohol, novocaine, or cold salt solution, but have discontinued the practice during the past fifteen years.

The patients who have phantom pain as a rule, soon become accustomed to the sensation, and do not make it a major complaint.

The experimental work of Doctors Herrmann and Gibbs, is very convincing and is a valuable contribution, and should be given a careful trial.

E. PAYNE PALMER (Phoenix, Ariz.): In the use of a non-absorbable suture we should use a suture that is not going to result in tissue irritation. Silk, linen and cotton, will produce a certain amount of tissue reaction, but annealed steel wire will produce very little if any tissue reaction.

Therefore, in carrying out the method that Dr. Herrmann has suggested, if annealed steel wire is used you will get very little tissue reaction.

EDWARD W. GIBBS (Cincinnati, Ohio): I should like to thank Dr. Palmer for his suggestion for the use of steel wire. We have had no experience with steel wire, but we hope that others may become interested in this problem from our studies, and that through their interest the ideal method of treating these nerves may be achieved. In this manner we may minimize the appearance of phantom limb pain in those who are returning from overseas.

KINETIC AMPUTATIONS AND PLASTIC RECONSTRUCTIONS OF FINGERS

OPERATIVE TECHNIC AND FUNCTIONAL RESULTS

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THERE is nothing new about the procedure for kinetic amputations. It was first developed by an Italian Army surgeon by the name of Vangetti, immediately after the first Italian-Abyssinian campaign, which was disastrous to the Italians, and in which many prisoners were taken. The Abyssinian's idea of taking prisoners was to amputate their left arm or left hand and then send them back to the Italian lines. After that campaign the Italians had a large number of hand amputees.

Vangetti did the experimental work; he is credited with it. However, he never performed the operation on any human. In 1900, Cici, of Pisa, performed the first operation on a human which is reported to have been successful. After that a few sporadic cases were done.

There is not much in the literature concerning kinetic amputations, until the first World War of 1914. After that in Italy, primarily DeFrancesco, Pierra, Pelligrini and to a greater extent Putti, of Bologna, developed these methods using various kinds of motor muscle tunnels and tendon tunnels, and arthrodesis of bone ends controlled by muscles to activate the artificial hand. Immediately after the war, Sauerbruch in Germany developed a tunnel through muscle for activation purposes, which was more commonly used.

The last war gave this type of technic great impetus. Kessler, of Newark, has done more than anybody else in this country to develop the procedure, not in particular the operative technic, which was pretty well standardized by Sauerbruch for this particular method, but in the development of the artificial arm and the mechanism of the arm through technicians to make it available for this work.

The subjects for this type of operation are any individuals with an amputation of the arm to a point about four to five inches below the acromion, remembering, however, that the upper arm amputa-

tions do not give the functional results that the forearm gives, for the same reason that we have less function in the leg in amputations above the knee.

The best subject is the patient with a bilateral hand or forearm amputation. In the bilateral cases it is possible to produce artificial fingers by tube and bone grafting, if the first and second metacarpal or any of the others that can approximate against the thumb are preserved with their muscle mechanism to produce a lobster-claw hand; or the Krukenberg operation to produce a lobster-claw forearm can be done on one side and then the kineplasty on the other. This gives the best functional arrangement because the loss of sensation is most important in the hand.

However, the cosmetic appearance of these lobster-claw hands and forearms is something that should be well explained to the patient. He should see the picture and it should not be done in an individual who is sensitive to the cosmetic appearance of the Krukenberg or lobster-claw hand.

The contraindications are briefly as follows: It should not be done on any patient whom you know is the type who will not co-operate. If you cannot have intelligence and co-operation, you cannot get a good functional result. It should not be done on any patient who feels that the arm is going to enable him to do heavy work. It is not designed for heavy work and cannot be used for heavy work. The ordinary hook and strap arm is better for the individual who wishes to do heavy work.

From experience with this over a period of years, there are certain reports which have appeared in the literature. The only two worth consideration are those from Sauerbruch's clinic and those reported by Kessler in this country.

It has been reported by Ted Horn that he was able to find 403 cases out of 1,500 that have been done in Sauerbruch's clinic four or five years after World War 1. Of those 403 cases he found that 83 per cent of them were using their arms daily and that the result functionally was satisfactory.

Of fourteen double amputation cases that he was able to follow in these 403, he found that ten of the fourteen were using their arms daily with good functional results, and the remaining were not using the arms.

Kessler was able to collect 276 cases in this country. This was about eight or nine years ago. Of these 276, two-thirds of that group

were wearing their kinetic arm and using them. Of that active group of two-thirds, 90 per cent were forearm amputations.

As against that type of result, Kessler surveyed 278 arm amputees who did not have a kinetic arm but the usual procedure, and he found that 12 per cent only were wearing an artificial arm for cosmetic purposes only and that only two persons were wearing a mechanical arm for functional use.

In Germany five years after the last war a review was made of 7,000 hand and arm amputations, and it was found that only 1.8 per cent of those 7,000 patients were wearing any kind of an arm which they were able to use in a functional way.

I think the quickest and best way to present the operative technic and some of the functional results is by a motion picture film.*

For the forearm there is a variation in the operative technic. The variation is this: We do not make any attempt to close the plastic operation by skin under cutting, but we apply a half-thickness skin graft for closure. Also, in the forearm we do not make deep muscle tunnels, only about one-third of the circumference of the muscle. This is done to produce satisfactory healing of the plastic procedure.

This matter is a little dramatic, and it probably is not as good as it seems. On the other hand given an individual with an arm amputation you start from zero, and therefore you cannot lose anything. If the indications are met, the functional results are very satisfactory; but like most of these procedures if the indications are not met, the functional results are not satisfactory.

* The author showed the film referred to. It was for the operative technic for the upper arm.

UNUNITED FRACTURES OF THE CARPAL SCAPHOID*

PRELIMINARY REPORT ON THE USE OF VITALLIUM REPLICAS AS REPLACEMENTS AFTER EXCISION

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DESPITE the different methods followed in the treatment of fractures of the carpal scaphoid, a considerable number of these fractures, especially those through the waist or through the proximal portions of the bone, fail to unite. Cutler estimates that this failure of union occurs in 30 to 40 per cent of all cases of fractures of the carpal scaphoid. The end result of such non-union is usually a chronic deforming arthritis with serious and permanent loss of function of the wrist.

Speed has emphasized the rather peculiar blood supply to this bone and its relation to non-union. He refers to the work of Obletz and Halbstein who examined 297 carpal naviculars from cadavers and found that in one out of seven there were no arterial foramina proximal to the constricted mid portion or waist of the bone. Normally, the blood supply is from two arterioles, one entering the tuberosity; and the other, a larger one, entering the middle of the bone to give off proximal and distal branches. These vessels although penetrating the bone are not considered true nutrient arteries.

Interference with these avenues of blood supply which so often occurs in fractures of the carpal scaphoid is believed to explain its predisposition to post-traumatic necrobiotic changes and frequency of delayed union or pseudoarthrosis. Compere and Banks point out that avascular necrosis of the carpal scaphoid is second in frequency only to the head of the femur. They state that fractures through the waist of the carpal scaphoid result in necrosis of the proximal fragment in about one-third of all cases.

Johnson studied the healing processes in experimentally produced fractures of the carpal scaphoids in dogs; he has shown that these bones although of the cancellous type, heal more slowly than larger bones. According to Speed, most of the surface of the bone is

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covered with smooth hyaline cartilage except for the rough ridge passing obliquely across the dorsal surface from the tuberosity to the lateral side of the medial surface of the base, where the carpal

FIG. 1. Blood supply to carpal scaphoid (Cave after Lexer): Fracture site (1) tuberosity, (2) waist, (3) proximal third.

ligaments are attached. The actual repair of a fracture of the carpal scaphoid, therefore, is never by subperiosteal callus but by strictly interfragmental osteogenesis which proceeds very slowly even under the most favorable conditions.

It is generally agreed that fractures of the tuberosity readily unite regardless of the character of treatment, that fractures through the waist of the scaphoid heal with adequate and prolonged immobilization; but fractures through the proximal third, particularly if fragmented, seldom unite despite all adequate measures. The cases in the latter group, therefore, are perplexing problems from the very beginning and because of the expectancy of non-union many authors have recommended radical measures, such as bone grafting or excision of the fragments, as soon as the injury is sustained.

Certain anomalies, particularly the most common one, the bipartite scaphoid, must be considered in making a diagnosis of a recent or ununited fracture. The division plane of a bipartite bone is usually transverse and situated in the middle portion. Usually the roentgenogram shows a clear space between the portions with the edges regular and smooth. However, in the presence of a local deforming arthritis, the interspace may not be so clear and to differentiate a bipartite bone from an old fracture followed by pseudoarthrosis may be exceedingly difficult. In such instances, a negative history of trauma and similar roentgenological findings in the other wrist may be deciding factors in the diagnosis.

Errors in diagnosis resulting in delayed recognition of the fracture, combined with incomplete reduction and inadequate and

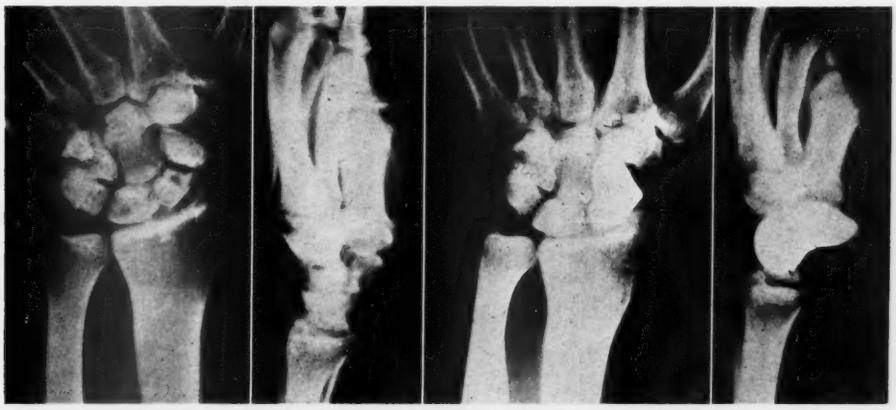
insufficiently prolonged immobilization of the fracture, are most common and no doubt account for the majority of cases of non-union. Perhaps the most frequent example of an ununited carpal

FIG. 2. Roentgenogram showing bipartite carpal scaphoid, bilateral.

scaphoid fracture is an injured wrist erroneously diagnosed without the aid of a roentgenogram as a sprain and treated without benefit of immobilization.

The actual development of non-union or pseudoarthrosis usually indicates a series of regressive phenomena, i.e., delayed union, non-union or frank pseudoarthrosis, aseptic necrosis, cystic degeneration and terminal deforming arthritis involving the radiocarpal articulation. In this connection it should be recalled that scaphoid osteitis with osteoporosis and atrophy, due to fracture, is known as Preiser's disease. From the standpoint of function, cases of pseudoarthrosis have been reported in which the function of the hand was little if any impaired and the patient apparently unaware of the defect. In such instances, however, a careful examination usually shows some limitation of motion of the wrist and some loss of power of the hand. A certain number of these cases of pseudoarthrosis remain asymptomatic only until the advent of another injury to the same wrist. This injury often is very insignificant in character and clinically considered merely a sprain of the wrist. Such cases are usually very resistant to conservative measures of treatment even with prolonged immobilization and present a most difficult therapeutic problem.

Considerable difference of opinion exists in regard to the treatment of ununited fractures of the carpal scaphoid. The character of treatment has varied from the most conservative measures, such



A B C D

FIG. 3. Roentgenogram showing fracture of carpal scaphoid; A and B, before operation; C and D after operation; (vitallium prosthesis replacement after excision).

as prolonged immobilization, to the most radical excision of all fragments or even excision of the entire proximal row of carpal bones. Briefly, the present concepts of treatment for ununited fractures of the carpal scaphoid may be stated as follows:

1. Prolonged immobilization, provided that the fragments are in a satisfactory position as recommended by Bohler, Soto-Hall and Haldeman, Speed and Bristow.

2. Multiple drilling of the fragments as recommended by Schnek, Steindler, Soto-Hall and Haldeman and Speed.

3. Bone pegging or grafting operations as advocated by Adams and Leonard, E. H. Smith, Murray, Burnett and others.

4. Excision of one or both fragments or even excision of the entire proximal row of carpal bones as advised by Cravener and McElroy, Davidson and Horwitz, Cotton, Hirsch, Cutler and Gurd.

5. Fusion of the scaphoid with the capitate and lunate as advised by Thornton.

6. Arthrodesis of the wrist as recommended in some cases by Smith-Petersen.

It is generally acknowledged that drilling and bone pegging or grafting operations are more likely to be successful than other methods, especially if the cases are carefully selected and the procedures carried out by experienced and skilled surgeons. Roth-

berg questions whether the satisfactory outcome in a grafting operation is due to the bone graft or to the drilling which is a necessary prelude to the insertion of the bone graft.

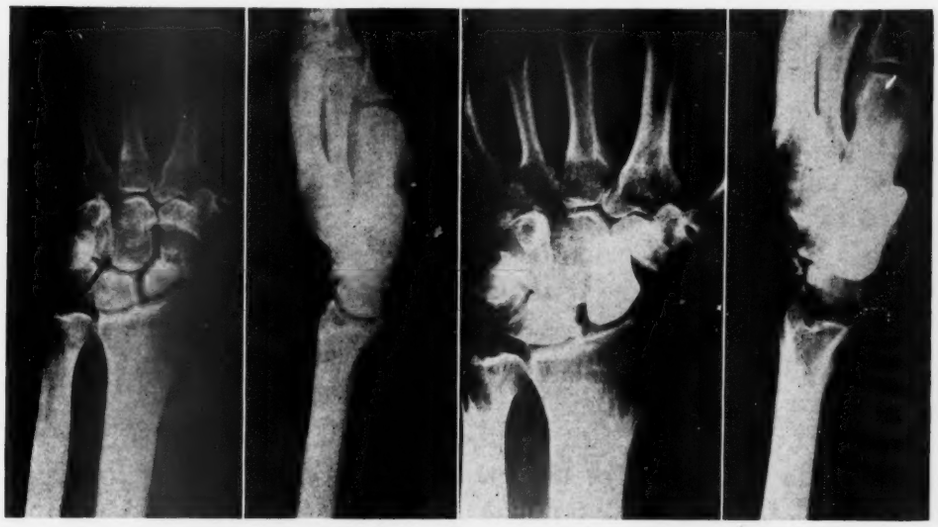
A B C D

FIG. 4. Roentgenogram showing fracture of carpal scaphoid; A and B, before operation; C and D, after operation; vitallium prosthesis replacement after excision. (Note marked arthritic changes including radial styloid process.)

An argument against the bone grafting operation is presented by General Bristow in his article, "Some Surgical Lessons of the War": "Fractures of the carpal scaphoid have had satisfactory results if they have been diagnosed early, reduced and held fixed and protected until consolidated. If they have been seen late or if an old fracture has been revealed by roentgenographic examination, disappointing results have been obtained when they have been submitted to either drilling or grafting operations. So much has been written about successful grafting that a note or warning must be sounded: it is very much the exception for a soldier who has a fractured scaphoid which has been grafted to continue in the Army except in low category. He cannot handle a rifle. Many experienced surgeons are rapidly coming to the conclusion that this operation has no place in the treatment of a soldier."

The partial or total removal of fragments although practiced to a considerable extent in former years is not generally favored at this time. This, no doubt, is because of the resulting disturbance of the normal relationship of the radiocarpal joint combined with a tendency to radial deviation of the hand and the frequently asso-

ciated degenerative arthritis, both contributory to continued disability of the hand. Grace states that excision of one or both fragments or of all the bones in the proximal row leaves a deformed



A B C D

FIG. 5. Roentgenogram showing fracture of carpal scaphoid; A and B, before operation; C and D, after operation; (vitallium prosthesis replacement after excision).

wrist with some permanent disability in the form of impaired function and frequently with pain on active use of the hand. Bohler states he has never seen a case in which the usefulness of the hand returned to normal after removal of the scaphoid bone. Adams and Leonard support these views stating "the removal either of the whole or a part of the bone is unsatisfactory to the patient as regards end function. The symptom pain is relieved but a varying degree of weakness in the wrist results."

On the other hand, Cravener and McElroy believe that "if a degenerative type of arthritis has already set in, no bone grafting or drilling will restore such a wrist to normal" and "for ancient ununited fractures with a degenerative arthritis, only removal of the proximal fragments will permit a cure."

Cotton in some instances removed the proximal fragments and reported that this procedure results in the relief of pain. Hirsch reports excellent results in nine cases following total removal with perfect return of function of the wrist and with no trace of radial deviation of the hand. He, however, advocates early extirpation of the bone before traumatic arthritis in surrounding bones develops.

Gurd is another advocate of excision of the carpal scaphoid for delayed union or non-union and states that he has been better pleased with the results of this form of operation than with those following either conservative treatment or the use of the bone graft.

Cutler states that while the results of the excision operation have not proved quite satisfactory, it is the treatment of choice in those cases in which reduction or union has failed and lameness of the wrist persists.

Davidson and Horwitz advise total and not partial excision of the fragments for ununited fracture, stating that the latter procedure often results in continued disability. They state, however, that excision should be done early and that if total excision is delayed, the efficiency of the procedure diminishes proportionately.

These divergent opinions indicate the difficulty in obtaining satisfactory results in the treatment of these ununited fractures. From the standpoint of uncertainty of cure, the ununited carpal scaphoid fracture is not unlike the "unsolved fracture" (of the hip) described by Speed a decade ago. Therefore, the ununited carpal scaphoid fracture might be designated the "unsolved ununited fracture of today."

We have had the opportunity at various times of performing all the above mentioned operative procedures with the exception of the intercarpal fusion as done by Thornton. Based on our experiences, we have come to the conclusion that multiple drilling and bone pegging or grafting operations are not suitable for the more complicated cases of fracture or non-union. In this group we would include the following: (1) Fresh fractures with the fragments badly comminuted and displaced, particularly those involving the proximal portion; (2) old cases of pseudoarthrosis with the fracture site either through the waist or proximal portions, and associated with local deforming arthritis, and (3) reinjury cases in which the clinical symptoms and the disability persist after an adequate period of immobilization.

In regard to treatment of this group of complicated cases, it would seem to us that there are but two alternatives. The first is the excision operation and the other is some type of an arthrodesing procedure. We believe the excision operation is the better. This, therefore, would be the operation of choice in the majority of these complicated cases. We should, however, bear in mind that the

excision operation, as is true in the other operative procedures, when carried out in this group of cases, is performed only with the expectation of partial relief of the symptoms and the disability.

In endeavoring to solve this problem it is natural to think of replacing the united carpal scaphoid with a prosthesis. That the replacement of a carpal scaphoid by a prosthesis is feasible is also suggested by the interesting case reported by Walker of a dislocation of a carpal scaphoid reduced by open operation. In this case, closed manipulation failed and on open operation, the scaphoid was found to be rotated 180 degrees. It was necessary to remove the scaphoid completely, after which it was replaced without fixation and full recovery followed.

At the present time metallic devices are used for the internal fixation of fractures, to correct or to prevent ankylosis and to fill skeletal defects. In addition to use of plates and screws, the more common practices, following the monumental work of Venable and Stuck, have been the use of vitallium cups in arthroplasties by Hopkins and Zuck, Smith-Petersen, Campbell, Burman and others; of vitallium ferrule caps for replacement of fragmented and displaced heads of radii by Kellogg Speed and the filling of a long bone defect with a vitallium prosthesis as successfully done by Moore and Bohlman.

A purpose of this communication is to report the use of vitallium replicas as replacements after total excision of ununited carpal scaphoid fragments in three patients. The results, while not entirely satisfactory in all three cases, are offered for what they are worth as an aid in solving the problem of the ununited carpal scaphoid fracture.

VITALLIUM REPLICAS

The actual use of a replica of vitallium as a replacement after excision of the fragments in cases of ununited fractures of the carpal scaphoid was premised on the belief that such a prosthesis would at least maintain normal relationship of the other bones of the wrist, prevent radial deviation of the hand and also might lessen or even prevent the untoward symptoms that frequently follow the ordinary excision operation.

The vitallium replica, used in our first patient was made from a mold of a carpal scaphoid taken from a skeleton and which was assumed to be of average size and shape. This replica was of solid

vitallium and weighed 29 Gm. Although the patient was quite satisfied with the operation and stated that his wrist was much improved, it was nevertheless believed that the prosthesis was of excessive weight and not a perfect fit.

To overcome these difficulties, hollow vitallium replicas were made which were patterned after a model scaphoid of average shape, determined from the mean of several scaphoids obtained from cadavers. These hollow vitallium scaphoids were made up in three sizes, small, medium and large and in pairs, right and left, to be kept on hand as "ready-made" replicas so as to offer some range of selection when needed by the operating surgeon. The weights of these hollow vitallium replicas, while not constant, were approximately as follows: small size, 12 Gm., medium size 14 Gm. and large size 17 Gm. For comparison, the average weight of human carpal scaphoids removed from cadavers was found to be between 4 and 5 Gm.

OPERATIVE TECHNIC

With the hand in full adduction and using a tourniquet, the scaphoid bone is exposed through a curved incision over the radial aspect of the wrist. The ends of the incision are curved toward the dorsal aspect of the wrist. The radial nerve and vessels and the abductor tendons of the thumb are retracted anteriorly and the extensor pollicis longus tendon is retracted posteriorly. A transverse opening is made through the capsule exposing the ununited scaphoid fragments. The fragments are then removed after which they are reassembled for inspection so as to serve as a guide in the selection of a replica of the proper size. The selected replica is then inserted in the scaphoid cavity of the wrist, care being taken to place the replica in proper position in respect to the articular surfaces of the adjacent carpal bones. The wound is then closed.

Following the operation, the thumb, hand and distal two-thirds of the forearm are immobilized in molded plaster of Paris splints with the distal phalanx of the thumb and the fingers free and with the wrist in about 30 degrees dorsiflexion, the optimum position for function. The plaster dressing is worn for about two weeks. After this the patient wears a leather gauntlet which is removed at intervals to permit physical therapy in the form of whirlpool and guided active exercises. After a few weeks, the gauntlet is removed at night and for increasingly longer periods during the day, but is worn for

several months after return to work, particularly if the work is of a character requiring considerable stress and strain on the wrist.

CASE REPORTS

CASE 1. F. J. R., a man aged forty-one, employed as a machinist at the Watertown Arsenal, was admitted on March 19, 1942. In October, 1939, he had injured his right wrist. This was diagnosed as a "sprain" and he had been able to continue at work without any difficulty. On October 15, 1941, he again injured his right wrist and this time was again treated for a sprain and was off duty for two weeks. Since this reinjury he continued to have pain, discomfort and weakness of the right wrist and was able to do his work only with difficulty.

Examination showed a fullness or thickening of the right wrist with local tenderness and limitation of wrist motions in all directions. A roentgenogram showed an ununited fracture of the carpal scaphoid with displacement of the fragments. There was increased density of the proximal fragment and also moderate arthritic changes involving the articular surface of the radius. The styloid process of the radius showed enlargement.

Immobilization of the wrist (including the proximal phalanx of the thumb) in a plaster dressing for a period of two months resulted in no relief of his symptoms.

Operation was performed on April 21, 1942 (two and one-half years after the original injury and six months after the reinjury). This operation consisted of total excision of the fragments and replacement by a vitallium prosthesis. Convalescence after the operation was uneventful. He was able to return to light work wearing a leather gauntlet five weeks after the operation. Five months after the operation the patient was re-examined. At that time he seemed well pleased with the results of the operation and stated he had "wonderful action of the wrist" but he had noticed a "grating" in the wrist upon certain motions and he did not have much grasping power in his hand. The wrist, however, appeared normal except for a slight thickening and some general tenderness. The wrist motions were limited to about 50 per cent of normal in all ranges. The patient was followed for a further period of several months but despite the continued wrist symptoms was able to continue at work. It was nevertheless concluded that the solid vitallium prosthesis was too heavy and not of the best fit.

A second operation was done on January 20, 1943. This operation consisted of removal of the solid vitallium prosthesis and the reinsertion of a hollow vitallium prosthesis. At operation the cavity was found smoothly lined and containing about 2 cc. of clear thin viscid fluid. The solid vitallium prosthesis presented the usual bright appearance.

Convalescence following the reoperation was again uneventful and he returned to light work twenty-six days after the operation. He has been

seen at frequent intervals and there has been slow but continued improvement in his wrist. For the past year he has worked with little handicap. At the present time there is no apparent deformity of the wrist. The wrist motions are fully 75 per cent of normal in all ranges and grasping power is equal to that of his left hand.

CASE II. J. L., a man aged forty-three, employed as a plumber at the Navy Yard, was admitted on February 8, 1943. He had fallen on the outstretched left hand on January 14, 1943. Since that time he had noticed pain and swelling in the left wrist. Further questioning, however, revealed that the patient had had a "sprain of wrist" in 1916. He also admitted recurrences of the "sprain" with pain and swelling of the left wrist and on frequent occasions had noticed a grating sound in his wrist.

On examination there was swelling or thickening of the wrist and local tenderness over the region of the scaphoid. Wrist motions were limited and painful and he was unable to assume the position of full grasp with the left hand. The roentgenogram taken January 15, 1943, showed an ununited comminuted fracture of the carpal scaphoid with post-traumatic joint changes including the articular surface of the radius. The styloid process of the radius showed enlargement.

Operation performed on February 19, 1943, consisted of total excision of the fragments and replacement with a vitallium prosthesis. The larger fragments of the scaphoid were found well fixed by surrounding adhesions but the two minor proximal fragments appeared as "loose bodies."

Convalescence immediately after operation was uneventful. Follow-up of this case, however, showed continued pain and stiffness of the wrist which necessitated wearing a gauntlet but he returned to light duty two months after the operation. Check-up examination seven months later showed no apparent improvement in the wrist condition and removal of the prosthesis was advised. This was done in September, 1943. Despite the removal of the prosthesis there was no immediate improvement in the condition and the partial disability persisted. However, a recent examination April 4, 1944, showed an increase in the range of wrist motions and a better grasping power of the hand. He is now doing a heavier type of work but is still wearing the leather gauntlet.

The operation with insertion of the vitallium prosthesis in this case, therefore, is classed as a failure. Nevertheless, this man's present status, from a disability standpoint is believed better than could have been expected had total excision been done without temporary placement of a prosthesis.

CASE III. A. B., aged twenty-five, a ship's cook in the Coast Guard, was admitted on January 22, 1943. Eleven months before he had fallen and injured his right wrist. He was treated with a metal splint for about seven weeks. Since the termination of that treatment he continued to have

pain upon wrist motion. The patient also stated that at the age of nineteen he had had a fracture of the same wrist. At that time his wrist was in a cast for three months and his wrist thereafter was perfectly well until his injury in February, 1942.

Examination of the right wrist showed no apparent deformity. The wrist motions were limited and painful, flexion being limited to 60 degrees and extension limited to 30 degrees. There was tenderness localized over the "snuff box" of the wrist. A roentgenogram of the wrist showed an ununited fracture through the mid-portion of the carpal scaphoid with slight cystic degeneration and arthritic changes involving the articular surface of the radius. There was also noted an enlargement of the radial styloid process.

Operation was performed on February 22, 1943, and consisted of total excision of the fragments and replacement by a vitallium prosthesis. At operation there was no bony union, the space between the fragments was filled with fibrous tissue and there were many adhesions extending from both fragments to the adjacent carpal bones and articular surfaces of the radius.

Convalescence immediately following operation was uneventful. Two months after operation he returned to duty. At the last check-up examination on May 10, 1944, the patient stated that for the past year he had been doing his regular duty as a ship's cook. He stated that he had had no difficulty doing this work and he also had been able to engage in sports, such as baseball. His only complaint at that time was a little discomfort in his wrist with the approach of rainy weather. Examination of the wrist at that time showed no deformity other than a prominence in the volar aspect of the wrist site of the rather pointed tuberosity of the scaphoid prosthesis. This prominence was more noticeable upon forced dorsiflexion of the wrist. Wrist motions were fully 60 per cent of normal and grasping power was equal to that of the left hand.

CONCLUSION

The use of a vitallium replica for replacement after excision of the fragments of an ununited fracture of the carpal scaphoid is in the experimental stage. While the results to date are encouraging, sufficient length of time has not elapsed to determine whether or not the use of these vitallium replicas will be of value in solving the problem of the ununited fracture of the carpal scaphoid. A further report will be made on these and probably other cases when sufficient time has elasped to determine the end results.

It would seem, however, that the greatest value of these vitallium replicas is in selected cases of ununited fractures of the carpal

scaphoid, such as (1) old cases of non-union, associated with local deforming arthritis, and (2) reinjury cases with symptoms persisting even after adequate and prolonged immobilization. These replicas also may prove to be of value in the treatment of fresh fractures of the carpal scaphoid when the fragments are badly comminuted and displaced, particularly those involving the proximal portion.

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DISCUSSION

CHARLES VENABLE (San Antonio, Texas): Since it has been known to be possible to use material that is not subjected to any chemical irritation, the irritation having been proven of course to be due to electrolytic action between the electrolyte and the material, all sorts of gadgets have been made of vitallium to fit almost any part of the body. Some of them have worked splendidly, and others do not work at all.

In this particular instance I think Captain Waugh has developed one that works and may be expected to work. I think we should resolve to the principle involved in the proposed application of different processes for different purposes of function.

In the replacement of a scaphoid the process is put into a stabilized area, and the function goes on about the prosthesis which in itself is immobile. You are not dependent, in this immediate area, upon the ligaments about the wrist joint or the tendons or the anatomical or physiological stability about the wrist joints, which must be taken entirely into consideration in making any kind of a prosthesis over a joint in expectation of stabilized function.

In the instance of the hip cap which is stabilized, the joint is stabilized and we expect and get function. In the instance of the artificial head of the radius as developed by Dr. Kellogg Speed, which is fixed, the joint is fixed. This radial head can be held and is fixed at the side of the ulna, and both pronation and supination is carried on in perfect manner. I have done a good many of them, and of course flexion and extension of the elbow is not interfered with at all.

However, if you were to switch over and undertake to make the upper end of an ulna even with the upper end stabilized onto the shaft, the elbow itself would not be quite so stable, although of a fair functional type.

If we go down into the knee, we find that the attempted prosthesis in using caps over the knee gives a loss of stability of the knee joint and function. For a period you will have a very fair function, flexion and extension; but after a while, as the fibrous tissue begins to tighten down about the joint, the motion will become more and more limited.

I attempted one or two with Willis Campbell and Carroll and two or three others with not good results because we found instability as well as a progressive limited function. You cannot cut off all the blood supply with metal and expect to have rehabilitation of the immediate attachments about the joint.

Of course, they make gall ducts and ureters and all those things, and there it does not make so much difference about stability. Probably the best one is the artificial testis, which seems to work all right.

Seriously, however, Captain Waugh is to be very greatly complimented for the detail it takes to work these out. You have to do a lot of figuring to make these gadgets fit and make them work. I congratulate Captain Waugh very much on this very original piece of work that he has done.

KELLOGG SPEED (Chicago, Ill.): Indications for replacement of the ununited carpal navicular bone might be conceivable on the basis of cosmetic, functional or anatomical requirements.

Surgical removal of the navicular alone, in my experience, gives no unhappy cosmetic evidence. After several years there may be a slight tendency for the wrist to sag slightly in radial flexion.

Removal of the ununited navicular may decrease the impaired function in the wrist caused by this lesion. This results by removing the dead bone which acts as a source of irritation and by ending the osteo-arthritic tendencies of neighboring carpal joints which set-up pain and which in turn lowers functional use. It is questionable, in view of the small yet necessary range of movement in the space normally occupied by the navicular straddling both distal and proximal rows of bones, whether a vitallium replacement of equal size would permit a full range of motion. A replica of reduced size might. My experiments on replacement of the head of the radius by vitallium caps lead me to conclude that although the vitallium surface is smooth and non-adherent, it does not prevent the formation of considerable inelastic connective tissue about the area of implantation. This tends to narrow the natural space left behind on removal of the bone and thus may eventually inhibit a normal range of motion. It is my belief that an analogy cannot be taken from the hip joint where there is a wide range of motion in all axes and where, after covering the head of the femur with a vitallium cap, there is early forced and extensive active and passive motion induced.

Anatomically, the loss of bone in the space normally occupied by the navicular, may not require refilling to lead to equal strength and anatomical support of the proximal row of carpal bones. Interpretations of this point could be made only after several years of observation on a series of replacements successfully performed. Captain Waugh should be commended for starting this investigation.

GORDON MURRAY (Toronto, Canada): I should like to compliment Dr. Waugh on his excellent work in replacing the scaphoid. I agree that where the proximal fragment is comminuted, or where there are arthritic changes, that might be an excellent method of undertaking this problem.

However, the question of aseptic necrosis alone of one or both fragments probably in itself is not an indication for this; in other words, it is not a contraindication to bone grafting.

I have done now well over one-hundred cases of bone grafting of the scaphoid, and in over 40 per cent there is aseptic necrosis either of the proximal or both fragments, leaving out those cases of arthritis that are not grafted.

With an aseptic necrosis with grafting, in all of the cases I have obtained a revascularization of the proximal fragment and union of the fracture except in two cases. One of those was a case in which the boy took off his plaster early himself and started to work with motion, and he got a non-union. Another resulted in non-union which, on grafting a second time, got a union.

So there is only one permanent non-union in over one hundred cases, and in all those with aseptic necrosis revascularization has taken place with the most excellent functional result. Those people go back to their original jobs.

S. POTTER BARTLEY (New York, N.Y.): Along the same line of reasoning, particularly about what Dr. Venable has said, about two years ago in a boy of twenty-five I removed the astragalus and replaced it with a vitallium astragalus. His functional result for the first year was good. By that I mean he had a reasonably good range of motion without pain, and he returned to his work as a mechanic in a shipyard, which is fairly heavy work.

During the second year the motion diminished, still without much, if any pain; but at the end of two years he has lost about three-quarters of the motion of his ankle, inflection and extension, and he has lost completely his supination and pronation in the foot.

However, I would say in evaluating him at the end of two years, that the functional result, because of being able to keep the anatomical contour of the foot, I believe is definitely better at this time than that which would have occurred from astragolectomy either with or without fusion.

CAPTAIN RICHEY L. WAUGH (closing): I should like to thank the discussers for their remarks. The only word I have to say in closing is this:

You will note in one of the two patients being presented—the Coast Guardsman—that there is a prominence in the volar aspect of the wrist. This was due to the pointed process or tuberosity of vitallium carpal scaphoid. In the ones that we are having made now, that point has been taken off. It is a blunter point and with these you do not have the prominence in the wrist.

TRAUMATIC NEUROCIRCULATORY DISORDERS OF THE EXTREMITIES

J. Dewey Bisgard, M.D.
OMAHA, NEBRASKA

IN both military and civilian practice there are encountered certain definite clinical entities which from the lack of definitive understanding have been designated post-traumatic neurovascular lesions of the extremities. In common with other lesions which reflect dysfunction of the vegetative nervous system, the signs and symptoms have a certain intangible character or a lack of concise pattern. For this reason and because the lesions follow trauma the afflicted often have failed to receive the proper and sympathetic consideration that they deserve. Too often the symptoms have been attributed to neuroses and malingering. And as a matter of fact a differential diagnosis is often difficult or impossible.

The underlying vasomotor disturbance manifests itself variously. In one group of cases the symptoms are predominantly those resulting from angiospasm, in another group, those resulting from vasodilatation and in many cases both exist simultaneously or intermittently. Immediately following most major injuries and often following minor ones varying degrees of pallor, coldness and numbness develop in the injured extremity. During World War I this condition, which came to be known as stupeur arterielle, was frequently observed. The condition followed woundless traumatism as well as penetrating or lacerated wounds and has been attributed to injury to the adventitia of the arteries. A simple contusion of the arm can make the hand and forearm so limp and colorless and the radial pulse so nearly imperceptible that a crushing injury to the brachial artery may be suspected. There are on record instances in which these vascular contractures have been so intense and prolonged that gangrene of the fingers or toes has resulted.

Fortunately, these phenomena are usually of short duration. They have been considered comparable to surgical shock of a limited nature; that is, shock limited to an extremity. During the last war there were many unnecessary amputations for stupeur arterielle. If there is not an early spontaneous release of vasospasm and recovery, novocaine injection of the regional sympathetic

ganglia should be done. Heat should never be applied to one of these ischemic extremities. This is a common and dangerous practice. It merely increases the metabolic demands upon an already inadequate circulation and thereby increases the likelihood of gangrene.

CASE REPORTS

An example of stupeur arterielle is presented in the following case report:

CASE 1. R. W., a man of twenty-four, entered the Hospital Department of the Union Pacific Railroad January 5, 1943, three hours after sustaining a gunshot wound of the right leg. The bullet had traversed the popliteal space. Immediately he was able to bear weight on the leg and seemed to have normal function of the leg and foot but within thirty minutes from the time of injury the leg became numb, cold, white and almost functionless. He had no pain except for a burning sensation at the site of injury. There was essentially no blood loss. On admission to the hospital, the patient was seen by a staff surgeon who made the following observation: The right leg presented a bullet wound of entrance on the mesial aspect of the thigh immediately above the condyle of the femur and a wound of exit on the lateral aspect directly opposite the point of entrance. The concavity between the hamstring muscles was obliterated but the space was not under tension. The foot and leg below the knee joint were very pale, cold and somewhat swollen, with slight but definite pitting edema. He executed all motions of the foot feebly and with difficulty. There was a stocking-like hypasthenia distal to the knee joint. Pulses at the ankle were not perceptible. The coldness, pallor, loss of sensation and of motor function increased with obvious impending gangrene of the toes and distal portion of the foot during the next twenty-four hours. The surgeon in attendance concluded that there was pressure upon the popliteal vessels and nerves from a hematoma or swelling, and so under anesthesia he explored the popliteal space and the calf of the leg through lateral longitudinal incisions. To his surprise, no hematoma or other source of pressure was found and the vessels and nerves were intact. No improvement in the circulatory status of the leg followed the operation. The patient was seen by me on the following day, at which time there was obvious gangrene of the great and middle toes and an area of superficial necrosis over the dorsum of the foot. (Fig. 1.) The distal two-thirds of the leg was cold, pale, numb and moderately edematous. On that day the lumbar sympathetic ganglia were infiltrated twice with novocaine. Following these injections there was a definite improvement in the color of the leg to the ankle and an increase in skin temperature. Following the

second injection, the pulse in the dorsal pedis and posterior tibial vessels became definitely perceptible.

Subsequently, the two gangrenous toes were amputated and the tendo

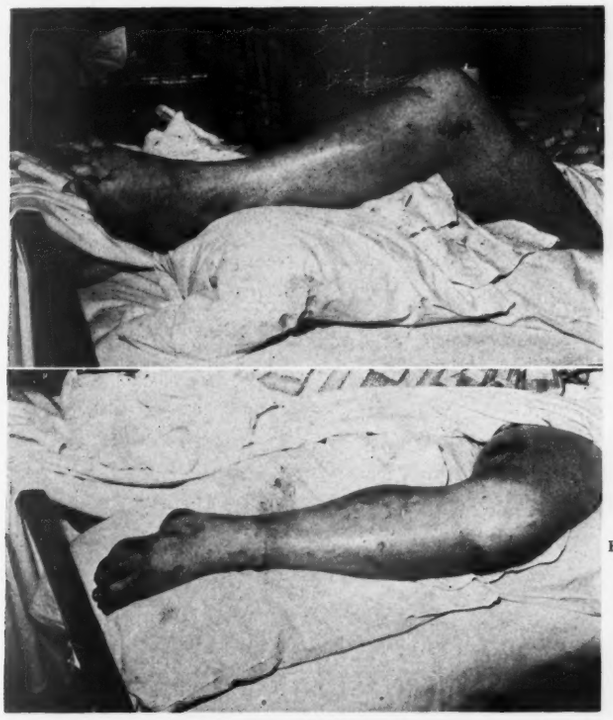

FIG. 1. Case I. A and B, note bullet wound's entrance and exit, incised wounds for exploration of popliteal space and calf, and the circulatory disturbance of the foot including gangrene of two toes.

Achillis was lengthened for an ischemic contracture of the gastrocnemius muscle. The swelling disappeared rapidly but complete recovery of sensation was delayed for approximately six months. The gastrocnemius muscle has remained somewhat shrunken, hard and weak with very little evidence of gain in function. The skin of the foot and distal half of the leg still retains a shiny atrophic appearance. The patient walks without a limp and the leg has satisfactory but much impaired function.

There seems to be irrefutable evidence that the profound circulatory disturbance in this case resulted from profound and prolonged vascular contracture or vasospasm. It may be conjectured that an earlier release of sympathetic control of the vessels would have salvaged a more normal extremity.

The deleterious effect of the application of heat to ischemic extremities is demonstrated in Case II:

CASE 11. A man of twenty-eight suffered a penetrating wound in the distal phalange of the middle finger of his right hand. A steel shaving penetrated and became buried in the pulp of the finger. He immediately experienced intolerable pain which radiated up the forearm to the elbow. The plant physician blocked the finger proximally with 4 cc. of 1 per cent novocaine containing adrenalin and removed the foreign body without difficulty. The hand was then soaked in a hot boric acid solution for twenty minutes. The patient returned the following day for a dressing. He complained of a persistence of numbness in the finger and inspection showed pallor, coldness and anesthesia from the proximal interphangeal joint distally with wrinkling and shriveling of the distal phalanx. Later the same day he was seen by me in consultation. There was obvious early ischemic gangrene of the finger which subsequently developed a line of demarkation just distal to the proximal interphalangeal joint. Amputation by disarticulation was done at this level.

A question of a mistake in the solution used originally for the anesthesia was investigated and this as a possible source of gangrene definitely excluded. The cause of gangrene can only be conjecture. The intolerable pain extending to the elbow immediately following injury suggests that angiospasm may have been a factor. The adrenalin and novocaine contributed an additional vasospastic factor. Undoubtedly, the immediate application of heat contributed to the development of gangrene because the ischemic extremity cannot dissipate heat through its circulation as it does normally and the increased metabolic demands of the tissues cannot be met by the impaired circulation. It seems likely that all three factors contributed.

Recovery from the acute state may be incomplete with the development of chronic neurocirculatory conditions. These result in certain trophic changes and contractures with and without pain; and since they are similar or identical to a group of manifestations which are considered under the inclusive term, causalgia, they will not be considered separately.

Causalgia was first described by Wier Mitchell during the Civil War. His description is so comprehensive that it may be quoted for its clinical value as well as its historical interest.

"The seat of burning pain is very various; but it never attacks the trunk, rarely the arm or thigh, and no oftener the forearm or leg. Its favorite site is the foot or hand. In these parts it is to be found most often where the nutritive skin changes are met with; that is to say, on the palm of the hand, or palmar part of the finger, and on the dorsum of the foot; scarcely ever on the sole of the foot or the back of the hand. Where it first existed in the whole foot or hand,

it always remained last in the parts above referred to, as its favorite seats.

"The great mass of sufferers described this pain as superficial, but others said it was also in the joints and deep in the palm. If it lasted long, it was referred to the skin alone.

"Its intensity varies from the most trivial burning to a state of torture, which can hardly be credited but which reacts on the whole economy, until the general health is seriously affected.

"The part itself is not alone subject to an intense burning sensation, but becomes exquisitely hyperesthetic so that a touch or a tap of the finger increases the pain. Exposure to the air is avoided by the patient with a care which seems absurd, and most of the bad cases keep the hand constantly wet, finding relief in the moisture rather than in the coolness of the application.

"As the pain increases, the general sympathy becomes more marked. The temper changes and grows irritable, the face becomes anxious and has a look of weariness and suffering. The sleep is restless and the constitutional condition reacting on the wounded limb exasperates the hyperesthetic state so that the rattling of a newspaper, a breath of air, another's step across the ward, the vibrations caused by a military band, or the shock of the feet in walking give rise to increase of pain. At last the patient grows hysterical, if we may use the only term which covers the facts. He walks carefully, carries the limb tenderly with the sound hand, is tremulous, nervous, and has all kinds of expedients for lessening his pain.

"The skin affected in these cases was deep red or mottled, or red and pale in patches. The epithelium appeared to have been partially lost, so that the cutis was exposed in places. The subcutaneous tissues were nearly always shrunken, and when the palm alone was attacked, the part so diseased seemed to be a little depressed and firmer, and less elastic than common. In the fingers there were often cracks in the altered skin, and the integument presented of all the affected part was glossy, and shining as though it had been skillfully varnished."

Often trigger points are demonstrable. The bones show much atrophy, the joints are swollen, stiff and painful. The muscles are atrophic and are or appear to be partially paralyzed. During World War I Meige and Athanassio-Benisty directed attention to the frequency of the relation of this condition to wounds of the median

and sciatic nerves in addition to injuries of the brachial plexus as described by Wier Mitchell.

In addition to the major causalgias incited by injury to the large nerves and vessels there are groups of minor causalgias which result from a great variety of lesser injuries, such as contusions, sprains, fractures, lacerations, and puncture wounds inflicted by animals. Not infrequently thrombophlebitis, especially the inflammatory type, gives rise to the syndrome, causalgia.

CASE III. M. K., a man of thirty-four, presented a migrating phlebitis of the left leg of eight months' duration. This had developed spontaneously and there had been no complete remissions. Pain and tenderness would leave one area only to develop in another. For six months there had been a superficial ulceration with weeping about the ankle. At the time of examination there was much swelling of the foot and entire leg up to the groin and there were areas of tenderness in the region of the saphenous vein above the knee joint. The skin over the dorsum of the foot and about the ankle had an atrophic glossy appearance with fissures through which serum exuded. Over this area the skin had a port wine color and the toes were alternately blanched and cyanotic. There was exquisite surface tenderness throughout the entire leg, and below the knee the leg was definitely colder than the opposite one. The dorsalis pedis and posterior tibial pulses were distinctly palpable. Exposure to cold and drying increased the pain which at times was intolerable. On occasion the patient was somewhat maniacal and asked that the leg be amputated. Skin temperature readings showed a constant large reduction as compared to the right leg but a good response or change in temperature following the immersion of the hands in hot water. The swelling of the leg diminished somewhat with bedrest and elevation but did not entirely disappear. Elevation, however, increased the pain.

The left lumbar sympathetic ganglia were injected with novocaine and there followed a prompt rise in skin temperature and complete relief of pain. The relief of pain lasted for approximately eight hours. On the basis of this clinical trial, a left lumbar sympathetic ganglionectomy was performed. The pain was immediately relieved and has not returned up to the time of this writing, three years following operation. The swelling had entirely disappeared in one week but returned to a mild degree when the patient became ambulatory and then did not entirely disappear for approximately six months. The skin about the ankle occasionally wept for the same period of time and then gradually lost the port wine color and developed a brownish pigmentation. The toes and the foot developed normal color immediately following operation and have retained normal appearance.

Both major and minor causalgias are associated with rapid demineralization of the bones in the affected foot or hand. Two members of this society, Hermann and Gurd, have contributed much to this subject. They are in agreement with others interested in this subject that the demineralization cannot be accounted for upon the basis of disuse atrophy. The loss of calcium takes place much more rapidly and completely than it does under circumstances of disuse. This fact was recognized by Sudeck who first described the condition in 1900. The atrophy occurs principally in the short bones of the carpus and tarsus and to a lesser extent in the epiphyses of the metacarpus, metatarsus, phalanges and the distal epiphyses of the bones of the leg and forearm. There is associated atrophy of the articular cartilage and periarticular structures as well as the muscles and skin of the foot or hand. In fact the changes in the bone are merely a part of the picture of causalgia as described above. Recovery from the neurovascular disturbance is accompanied by remineralization of the bone. Fontaine and Herrmann are of the opinion that recalcification is never completely achieved.

These bone and joint changes are the principal source of prolonged disability and a source of distress, long after the superficial tissues have regained normal appearance.

Sudeck's bone atrophy is seen not infrequently in association with fractures about the wrist joint but may follow relatively trivial and minor injuries as in the case that follows:

Case IV. O. N., a physician of forty, lacerated the thener web of the left hand and within forty-eight hours developed marked swelling of the entire hand to a level just above the wrist. Although the skin had a port wine color, there was an actual decrease in skin temperature. At no time was there evidence of infection. The wound healed by primary intention and there was no suppuration. Furthermore, at no time was there fever, an elevation in the leukocyte count or an adenitis. The swelling persisted without change for four weeks and then gradually receded during the subsequent four weeks. There were superficial manifestations of causalgia, severe pain, hyperesthesia and atrophy of the skin. Acute bone atrophy developed in all the carpal bones and the distal epiphyses of the ulna, radius, metacarpals and phalanges. Demineralization was so complete at one time that the outlines of some of the carpal bones were entirely lost and the roentgenologist expressed the opinion that there was complete destruction as the result of osteomyelitis. However, recalcification gradually took place but was incomplete. Films made two years after the injury

showed much less density in the affected bones than in the comparable ones of the right hand. (Figs. 2A, B and C.) At this time essentially normal function of the left hand had been regained.

A

B C

FIG. 2. Case IV. A, one month after injury, showing the moth-eaten appearance of early but advanced acute bone atrophy. B, two months after injury. Demineralization of the carpal bones has progressed to an extent that the outlines of the individual bones are indistinct. Note decalcification of the epiphyses of the long bones of the hand and fingers and of the distal radius and ulna. C, one year after injury. Compare incomplete recalcification of the left hand with the unaffected right.

This case illustrates a dangerous fallacy in the interpretation of roentgenograms. Upon the basis of roentgenograms alone it may be

impossible to distinguish this type of bone atrophy from osteomyelitis. Such findings can be interpreted only in connection with the entire clinical picture.

The disturbances in cutaneous sensation vary from extreme hyperesthesia to complete anesthesia and frequently there is parasthesia. There is also deep tenderness.

The treatment of post-traumatic neurovascular lesions varies with the individual case. The acute vascular contractures with impending gangrene are emergencies, demanding immediate efforts to relieve vascular spasm by means of novocainization of the regional sympathetic ganglia or periarterial sympathectomy. Heat should not be applied to these extremities.

Before treatment is undertaken in chronic cases a careful neurological and psychiatric study should be made in an effort to exclude compensation neuroses and hysteria. All doubtful cases, and there are many, should be looked upon as true causalgias and treated accordingly until a diagnostic therapeutic trial has proved them otherwise. To dismiss them simply as psychogenic does a great injustice to these sufferers.

Major causalgias associated with injury to major nerves such as sciatic, brachial plexus and median may be relieved by such procedures as neurolyses when the nerve is imbedded in scar, excision of neuromas when present, repair of a nerve when partially severed and by excising foreign bodies such as bullets or shell fragments in close proximity to these nerves.

Every case should be examined carefully for the possible presence of a trigger point, a discrete sensitive area or nodula. Pressure over this area is likely to excite a paroxysm of pain. Livingston, who first described these trigger points, has reported complete relief in a series of cases following either novocaine infiltration or excision of these points. I have had similar gratifying results from excision of trigger nodules in two cases, one a small neuroma in the periosteum of the ulna resulting from a blow at that point.

Minor causalgias and particularly the bone atrophy of Sudeck following fractures or other injuries may be prevented by the early institution of physical therapy and once developed this form of therapy probably shortens the otherwise long period of recovery.

Gurd has presented evidence that in cases of fractures Sudeck's bone atrophy can probably be prevented by early application of non-padded plaster casts or similar tight rigid dressings to the

extremities. This prevents the edema which may be a determining factor in this condition. In cases in which atrophy and the other neurovascular disturbances have developed, he confines the patient to bed with the limb elevated until the interstitial edema has disappeared. A silk stocking is then placed on the extremity and a plaster of Paris bandage applied. The bandage is made to cover the fourth and fifth toes, and is accurately molded to the contour of the leg. A heel or walking iron is applied to the leg cast and immediate weight bearing insisted upon. Since patients with acute bone atrophy are extremely fearful of pain from use of the extremity, much reassurance and encouragement are necessary.

In cases in which there is no definite evidence of involvement of nerves or demonstrable trigger points, or in cases of this sort in which the direct attack has failed, treatment to interrupt the sympathetic innervation of the extremity should be carried out. The simplest and most conservative method should be utilized first; that is, novocaine, pontocaine or urea injection of the stellate or second and third sympathetic ganglia for lesions of the arm, and injection of the lumbar ganglia for causalgias of the lower extremity, as devised by White, DeBakey and Ochsner. A single injection may result in permanent cure, but if only temporary relief is obtained, repeated injections may bring about a cure. If this method fails, one of two radical attacks are available: either the periarterial sympathectomy of Leriche or cervicodorsal or lumbar sympathetic ganglionectomy.

Because the patients in the more severe cases are likely to become addicted to morphine, every effort should be made to obtain early relief of pain.

Certain painful amputation stumps fall into the category of causalgia. These are stumps in which there is no evidence of an amputation neuroma and in which the skin displays evidence of vasomotor instability such as edema and red or bluish discoloration. They are principally the stumps of amputations between the knee and ankle. I have one case of this type which was entirely relieved following excision of a painful nodule in the scar which proved to be an epidermal inclusion cyst. On occasion an attack upon the sympathetic innervation may be indicated.

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DISCUSSION

EVERETT P. COLEMAN (Canton, Ill.): Dr. Bisgard's very excellent paper covers a great variety of pathology, extending from stupeur arterielle to the commoner and more troublesome cases of edema of the leg following fracture of the tibia.

Dr. Bisgard was kind enough to send me a copy of his paper, and in it he refers to the difficulties in diagnosing, or differentiating, rather, between cases of neurocirculatory diseases, neurosis and malingering. This is quite easy to understand, because all three conditions may occur in the same patient.

Take for example an individual who is covered by industrial insurance, or who has an insurance policy against injury. If he sustains an injury that produces rather unusual symptoms, such as more pain, more edema, more reaction around the joint than is ordinarily expected, and if under these circumstances this patient does not get well when his doctor ordinarily thinks he should, and if the doctor does not recognize the fact that certain neurocirculatory conditions are occurring, that fact soon becomes obvious to the patient. He then, because of a feeling that his condition is not understood, that his pain is not appreciated, tends to develop an anxiety neurosis based on the fear that further complications may occur and that they also will not be identified.

Furthermore, when that patient finds out, after a bit of observation, that a continuation of symptoms may bring about rather satisfactory

financial adjustments, it is very easy again to understand why, in addition to real disease, he might develop that complex commonly known as "compensationitis."

However, I would like to limit my discussion very largely to one condition that Dr. Bisgard has mentioned, that is, Sudeck's atrophy of the hand and wrist. With this I have had a little experience and a lot of trouble.

Sudeck's atrophy is supposed commonly to occur in those patients who have had a rather minor injury of the forearm or wrist. I have seen it in two cases in very old people, associated with a Colles' fracture. In each of these when the fracture was reduced perfectly, when adequate splinting was applied, each one was complicated by a rather severe bone atrophy of the Sudeck type, and the end result in each case was very unsatisfactory.

However, this condition occurs much more commonly in younger, rather middle-aged individuals, and those in whom I have seen it have all had an injury, usually a fall, with a moderately painful reaction. In these cases the pain would be sufficiently severe so as to suspect a fracture. There would be no deformity, but one would suspect a possible fracture of the lower end of the radius or one of the carpal bones. This would be ruled out by *x*-ray.

When this condition occurs the rather common advice given to the patient is, "It's just a sprained wrist; go ahead and use it, and if it hurts apply heat; soak it in hot water."

Dr. Bisgard brought out very nicely the disadvantages of the application of heat. We have seen in these patients within from one to four weeks after this type of treatment, the beginning atrophic changes that may occur. They will not be evident in the *x*-ray in one week, but they not uncommonly are visible in four weeks.

When these cases are seen later, the common experience of the patient has been that after the allegedly sprained wrist, he has more pain, swelling, edema, and then he is advised to have diathermy. His disability is lasting longer than it ought to last, so diathermy is recommended to speed up the period of convalescence, and it simply makes a bad matter worse.

Usually the patient is the one who is the first to notice that diathermy is doing harm rather than good, and he commonly quits it of his own accord.

I believe the answer—there is no real answer as yet—but I believe a definite lesson to be learned from this condition is that in any injury of the wrist, hand or forearm, which is sufficiently severe that you may suspect a fracture, and the *x*-ray shows a fracture does not exist, that we should bear in mind the possibility that once in a while Sudeck's atrophy does occur.

I think there is a certain type of patient in whom it is apt to occur, but time is too short to go into that now. Nevertheless, we should bear it

in mind, and routinely we should immobilize these joints and wrists as though a fracture did exist. Immobilize them completely and firmly, not for long, usually a period of seven to ten days. They should be inspected every two or three days. The immobilization should continue until all swelling and tenderness has subsided, and this ordinarily will not take long.

I believe by doing this that complications can many times (perhaps not always) be avoided. And if it does occur, I believe the early injection of novocaine in the region of the stellate ganglion, a method which I described in 1937 before the Western Surgical Association, will sometimes be of real value and will avoid the necessity of further radical surgery.

HOMER D. DUDLEY (Seattle, Wash.): I have no intention of attempting to add anything to the scientific phase with respect to injuries of the hand and the various changes occurring in the neurovascular systems of the extremities. I do want to add a point which I believe is of practical interest, and I may preface it by saying that it has been my privilege to examine several thousand injured workmen for the Department of Labor and Industries of my State, and among these a great many injuries of the hand.

During the early part of my experience in examining these patients and attempting to give the Department an evaluation of their disabilities, I became prejudiced, as I believe most of us have, in assuming that a trivial injury could not produce the disability which is often alleged.

One is often prejudiced when he examines a patient with neurocirculatory disorders, who is covered by industrial insurance or private insurance carrier; but I have seen this condition occurring in housewives, also two of my professional friends, in whom there was no liability on the part of an insurance carrier, and they had all the symptoms and associated disabilities. I have had occasion to review as many as eight such patients over a period of fifteen years, long after the claimant's award had been spent, and still had all their symptoms with only variations of relief.

In January, of this year, I reviewed a series of these cases and reported them before our local Surgical Society. I came to this conclusion:

We do not know the cause of the symptom complex "causalgia." Dr. W. K. Livingston has given us somewhat of an "out" by referring to a group classified as "causalgic states" but it does not answer the question. We still have the patients and we still have them suffering with this disability.

When by differential diagnosis true causative factors have been excluded, such as post-traumatic neuromas and known neurocirculatory lesions, then the diagnosis of causalgia may be made.

For medicolegal purposes, we should admit we do not know the cause of this disease or its cure and cease to go to court and testify to speculative and conjectural theories. Why should doctors be penalized because they

did or did not administer a certain form of treatment when the symptoms continue inevitably without relief from any form of treatment?

The insurance carriers and the Departments of Labor and Industries, who compensate workmen for these disabilities, should admit the diagnosis and treatment is not known and should give the proper aware of permanent partial disability.

Louis G. Herrmann (Cincinnati, Ohio): Dr. Bisgard gave me a copy of his paper and asked if I would say a few words about the problem.

Earlier I talked about the prevention of some of these complications, and I should like to re-emphasize some of those points again.

I am sure that many of the complications which Dr. Bisgard has described can be prevented, but after they are once established, the reflexes become permanently established in the nervous system, and it is very difficult then to remove either the symptoms or the effects.

I think many of the people who have symptoms many years after an injury have them, not because of the original injury, but because of reflexes which have been set up in their nervous system, as a result of the injury.

The whole problem of post-traumatic painful osteoporosis, as Fraser Gurd, John Caldwell and I have written about many times, is still in an unsettled state. We are convinced, however, that much can be done to prevent such complications to injury. Do not allow the symptoms to go on indefinitely before adequate treatment is given. Do not consider them to be occupational neuroses or compensation neuroses, but realize that these patients have real complaints, and see if you cannot relieve them either by blocking the sympathetic ganglionated chains with novocaine, by periarterial sympathectomy or by some physiotherapeutic measures.

Secondary vasospasm is one of the important disturbances which must be recognized early because reconstruction becomes difficult after trophic changes in the muscles have occurred, or after extensive thrombosis of small blood vessels has taken place.

If you will recognize this ischemia early and consider it to be the result of high grade peripheral vasospasm, then paralysis of the sympathetic nervous system impulses by novocaine or by surgical operation will usually prevent most of these complications.

Fraser B. Gurd (Montreal, Que.): As the essayist and as Dr. Herrmann have indicated, I have had an interest in this condition for a great many years. My specific interest commenced about 1924, and in the interval I have tried to understand the condition and have tried to learn something about it.

I was going to say none of us understand the condition; at any rate I do not understand the condition, even after having spent a lot of time trying to understand it and having read the literature which, as you know, has been almost entirely European.

Of the ninty-two reports in the literature on considerations of the subject, only three of them were in English in 1935. All the others were either in German or more particularly French.

There is the case of a man, forty-nine years of age, who fell off his bicycle on July 4, 1943. An *x*-ray* was taken to prove that he did not have a fracture. He was not treated,—I was going to say "adequately." He was hardly treated at all except for the fact that as his hand was stiff and he was complaining of it, about the middle of August manipulation under an anesthetic was carried out, and from that moment his condition became extremely grave. The hand, wrist, forearm as far as rotary movement was concerned was completely lost. In our opinion the extreme grade of osteoporosis which was evidenced was brought about by the manipulation under an anesthetic in a hand which was suffering from this painful osteoporosis.

He came under our care and was put to bed. Plaster was inadequate because it was not possible to get rid of the edema. If the edema can not be disposed of and an unpadded plaster which absolutely fits the limb cannot be applied, the use of the rest that the plaster gives is inadequate.

Periarterial sympathectomy was done at this time, following novocaine injections of the ganglia, which resulted in some limitation or minimizing of the edema. But no appreciable improvement was noted in the patient's condition. We saw him and had him as a patient in the hospital for most of the intervening time. His condition was extremely grave and pitiful. He came into the group of cases that Dr. Bisgard mentioned in his quotation from Dr. Weir Mitchell. If one walked past the foot of his bed, he would scream with the pain. All the joints of the hand, the carpus, the elbow and the shoulder were so painful that the little bit of movement transmitted to his bed by walking across the floor was sufficient to make him scream with pain.

He demanded that we do something more, and we did a stellate ganglionectomy. There was marked osteoporosis of the humerus even though none of the *x*-rays showed this very well.

Patchy osteoporosis occurred in consequence of the nimiety of blood supply, which in our opinion is dependent upon the pain that the patient experiences.

I do not believe anybody knows what it is,—whether it is the acetylcholine discharge from the nerve ends, or what it is that is responsible for the atrophy of the bones and the atrophy of the cartilages.

In any event, about three weeks ago the patient demanded that his arm be amputated. His arm was amputated at the shoulder. He is not much relieved, but we are hopeful that with the specimen we may be able to add something to our knowledge of the pathology of the disease.

* Dr. Gurd produced pictures to illustrate his discussion.

J. Dewey Bisgard (closing): First, I want to thank my discussers.

In the paper I included some discussion of the difficulty or impossibility of differentiating between causalgia and anxiety neuroses and malingering.

Dr. Herrmann brought out a very important point; That if we want to relieve these individuals it is necessary to give very active treatment very early. I think we are inclined to delay too long in attacking the sympathetic nervous system, either the stellate, the upper dorsal or the lumbar ganglia, or periarterial sympathectomy. As he pointed out, when patients get definite pathways established, oftentimes it is too late really to do them the service that could have been accomplished earlier.

TRANSCONDYLAR FRACTURES OF THE HUMERUS TREATED BY DUNLOP TRACTION*

REPORT OF TWENTY-ONE CASES

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OUR experience with the so-called lateral traction for the treatment of transcondylar or dicondylar fractures of the humerus in children, dates from the early part of 1939

FIG. 1. Case A. L., March 31, 1939. A, anteroposterior view on admission together with anteroposterior and lateral views taken twenty-four hours later after arm was manipulated and placed in flexion. The position here seems satisfactory.

following a description of this method by John Dunlop.[1] John E. Sullivan now in the Armed Forces, but at that time responsible for the treatment of fractures on our Service, supervised the early cases and showed several of these children at the 1942 Annual Fracture Day Meeting of the New York and Brooklyn Regional Fracture Committee. Previous to 1939 we had used the acute flexion method as described by Jones. Our incidence of deformity

* From the Children's Surgical Service, Bellevue Hospital, New York City.

was high, however, and we therefore welcomed a new method. To date we have employed it on a total of twenty-one patients. This type of fracture was most accurately described by Dunlop when

FIG. 1. Case A. L., April 5, 1939; B, lateral view showing posterior displacement of lower fragment while in flexion. The arm was then placed in lateral traction and two views at the right show position of the fragments nine days later. C, March 25, 1944; roentgenograms taken five years later. This child has a very slight decrease in carrying angle but with perfect function.

he described it as running through the broadened distal end of the humerus and through the olecranon fossa. He also drew attention to the typical fish-tail appearance of the distal end of the proximal fragment.

Generally speaking, we have followed most of the details outlined by Dunlop in attaching the traction immediately upon admission to the forearm up to the elbow, elevating the side of the bed and administering sedation, usually small doses of morphine. The weight

FIG. 2. Case M. G., May 10, 1941. A, roentgenogram taken on admission. Note the typical fish-tail appearance of the distal end of the upper fragment. B, May 10, 1941. Within twelve hours after application of traction note the almost perfect reduction of fragments. C, March 25, 1944. Three years after injury. This boy has a definite decrease in carrying angle with perfect function.

is then attached to the forearm with counter-traction to the arm. (Figs. 5A and B.) *X*-rays are then taken with the portable machine at intervals of every few hours. In a great majority of these patients

FIG. 3. Case A. N., May 31, 1941. A, the two views at the left are of a compound fracture on admission. Manipulation under anesthesia resulted in tracheal obstruction due to vomiting making bronchoscopy necessary. The view at the right represents the position after ten days in traction. B, four months and three years after fracture. In the lateral view to the left note the filling in with bone of the periosteal tube which was carried posteriorly with the distal fragment at the time of injury. Traction here did not correct the posterior displacement but did correct the rotation of the distal fragment. This boy has perfect functional and cosmetic result.

good reduction is obtained within twelve to sixteen hours. A few, however, are slow in reducing and at the present time we believe that if after twenty-four hours a satisfactory reduction has not been

attained or if at least the fragments are not showing a progressive tendency toward anatomical replacement, an anesthesia should be administered with the traction in place and manipulation done. The

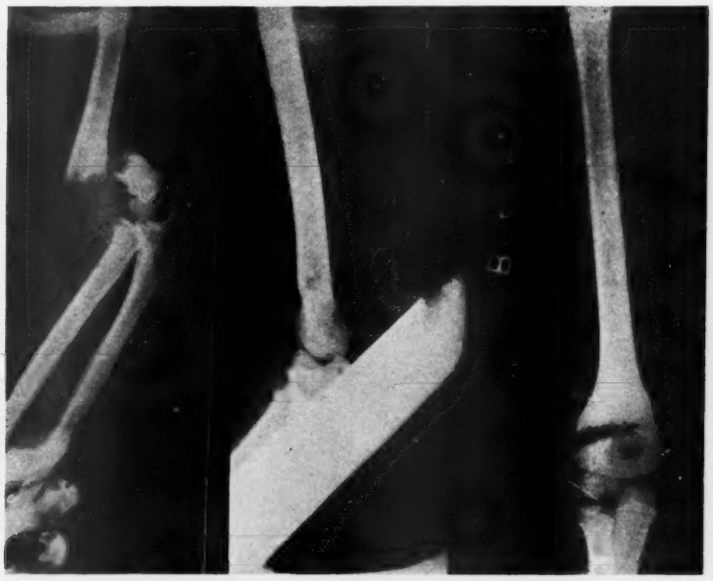

FIG. 4. Case T. B., October 1, 1941. The lateral view at the left was taken on admission. The elbow was tensely swollen and there were many abrasions. The two views at the right are after nine days in traction. A five months' follow-up revealed a slight loss of extension.

amount of weight on the forearm and countertraction on the arm varies with the patient. We use from three to six pounds on the forearm and from one to three pounds as counter weight on the arm. Several of these cases present marked swelling about the elbow and in all instances the soft tissue swelling is markedly diminished with this means of treatment. The fractures in two of our patients were compounded and both of these obtained good results. In one instance the distal fragment was displaced anteriorly probably due to excessive weights in both directions. The weights were reduced, the patient was given an anesthetic and manipulated and an excellent result was obtained.

We have allowed the traction to remain in place for varying lengths of time, usually two weeks although in a few instances it remained as long as three weeks. We have been inclined to allow traction to remain until union is fairly firm, not using a plaster thereafter but have usually placed them in a sling encouraging active motion.

The narrow oblique fracture surface which is always present in these children, makes retention of reduction difficult with any other method except traction. Previous to using this method many of our

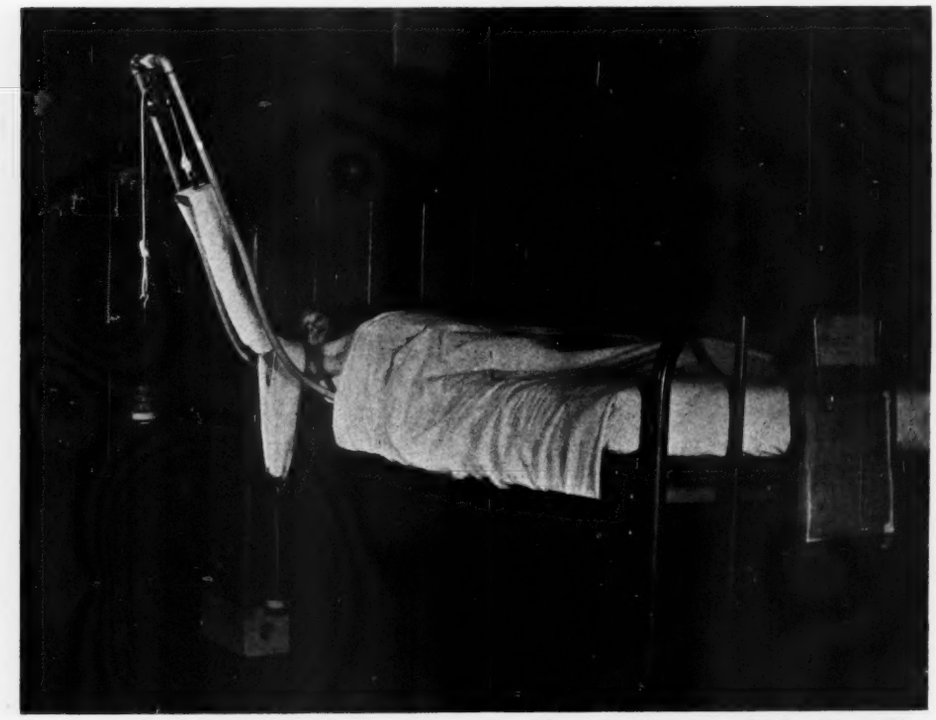

FIG. 5. A, the apparatus used for lateral traction. Note the elevation of side of bed. The amount of flexion at the elbow can be regulated by altering the position of the pulley or by the amount of weight used for countertraction.

fractures appeared to be fairly satisfactorily reduced by inspection of the *x*-ray films, but we believe that it was a rotation of the lower fragment in relation to the upper one that caused the bad results, chiefly alteration of the carrying angle. A moderate amount of rotation is difficult to detect accurately by *x*-ray. We believe that the traction method does away with rotation and even though traction may not completely correct posterior displacement of the lower fragment, we still get an excellent functional and cosmetic end result.

While the necessity for relatively long hospitalization in children treated by this method is not a serious problem in a City Hospital such as Bellevue, we believe the end results are so far superior to those attained by the known ambulatory methods that it is well worth while in all economic groups.

Of the twenty-one cases, two are recent and it is too early to evaluate end results. One of these was a girl thirteen years of age with comparatively little original displacement. She was treated on

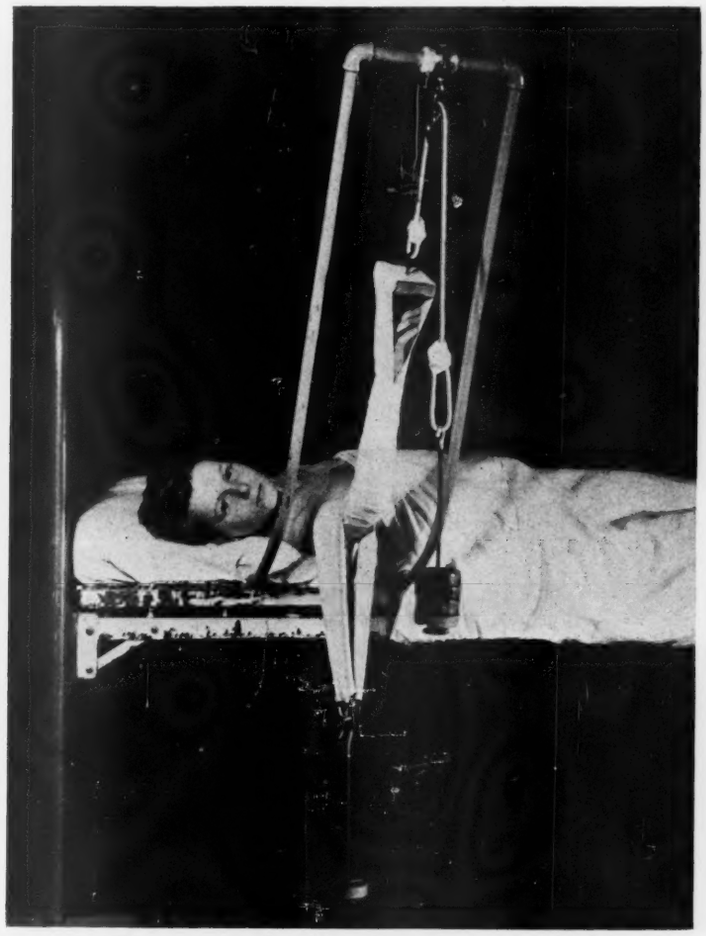

FIG. 5. B, another view of traction apparatus.

the Adult Ward. After one week in Dunlop traction, during which time the fracture was perfectly reduced, the surgeon in charge removed the traction and applied a plaster splint. A moderate amount of posterior displacement of the lower fragment occurred indicating that traction was removed too early. This patient will, however, get a good clinical result. The second patient admitted on April 8, 1944, was a boy of five who presented a wrist drop. Good apposition of fragments was obtained and there is good union. The wrist drop is rapidly improving and when seen a few days ago seemed to be on the way to an excellent result.

Fourteen of the other nineteen patients have been followed. The five not followed were comparatively simple cases who had good reductions and seemed to have excellent prognosis on discharge. One of these was a resident of Canada.

FIG. 6. Nine of the patients seen at a recent follow-up. The boy second from the left and the one at extreme right both have decreased carrying angles of the right arm. The other seven children present perfect functional and cosmetic results.

Eight patients have perfect end results. Two have decreased carrying angles, one slight and the other one quite definite, both with perfect function, however. One has a very questionable increase of carrying angle but with perfect function. One child presents a prominence of the medial humeral condyle but with perfect function. One, after a two months' follow-up had slight limitation of flexion but full extension and no other deformity. One whose follow-up ceased at five months had a very slight loss of extension. (Fig. 4.) We believe that both of these latter patients, if followed for sufficient length of time, would have perfect results.

REFERENCE

1. DUNLOP, JOHN. Transcondylar fractures of humerus in childhood. *J. Bone & Joint Surg.*, 21: 59–73, 1939.

DISCUSSION

JOHN DUNLOP (Pasadena, Calif.): I was pleased to be asked to discuss Doctor Allen's paper on transcondylar fractures of the humerus, because I am extremely interested in this fracture.

My attention was first called to the difficulties of its reduction in 1927, and it was first discussed by me at the Western Surgical Society at Omaha the following year. It had been my misfortune to see several cases of flexion deformity following improper reductions, and having had an experience of using traction in a badly comminuted fracture of the lower end of the humerus with remarkable reduction of the fragments and restoration of perfect function, I decided to use traction in a transcondylar case to see if a more perfect alignment might be obtained.

In the first case on which traction was used, the alignment was practically perfect and function likewise perfect. Since that experience, I have treated every transcondylar fracture in this manner with most satisfactory results. I am definitely of the opinion that should this method of treating transcondylar fractures be universally adopted, there would be considerably fewer permanently flexed elbows. No doubt, all of you have seen such deformities and many of you have one or more acquaintances with such deformities.

The diagnostic point of the fracture, when the first *x*-ray film is seen, is the fish-tail appearance of the lower or distal end of the proximal fragment. This appearance is caused by the fracture line crossing the olecranon fossa. When this appears, we may be quite certain that the fractured surface of the humerus is so thin or is beveled to such an extent that coaptation of the fractured surfaces is extremely difficult and even more difficult to hold. Should these surfaces be somewhat rotated one on the other, fixation is more likely possible; and the more the rotation, the more positive the fixation even to the point where the fractured surface of the distal fragment will fall into the thin surface of the olecranon fossa and by means of this produce a locking of the fragments. It is this type of alignement that destroys the olecranon fossa and permanently interferes with extension, for when the olecranon fossa is obliterated, there is no place for the olecranon to go when extension is made. So just to the extent that this olecranon fossa is filled or obliterated, so will extension be restricted.

My attention has been called to the prevention of Volkmann's ischemic paralysis by this method of treatment by some of my colleagues. I once had such a case, where all of the early symptoms had appeared, which proved this suggestion. The fracture had been reduced and plaster applied. As soon as the cast was removed and elevated traction applied, the symptoms immediately cleared up.

Because so little publicity followed my presentation in Omaha, I decided to present the subject fully as my Chairman's address at the American Medical Association's Orthopedic Section Meeting in San Francisco, 1938. Following the publication of this paper in *The Journal of Bone and Joint Surgery*, considerable interest was aroused, and it was not long before I began to hear of the use of the method far and wide. It has been a great satisfaction to me to hear from so many of my colleagues that they are adopting this method of reduction as a routine and even have added to the simple method I have advocated. As one of the men remarked "so little for so much."

I, especially, am pleased that Doctor Allen and his group at Bellevue have adopted the method; and I believe they are among the first who have been convinced as to its value. It has been a great pleasure to hear Doctor Allen and to learn of his success.*

EDGAR L. GILCREEST (San Francisco, Calif.): The results of Dr. Allen and Dr. Gramse in the treatment of transcondylar fractures of the humerus by the Dunlop Traction was most gratifying and they are to be congratulated. I am of the opinion that a great many more transcondylar and supracondylar fractures can be treated by a closed method than are being done. I wish to call your attention to the method which I used in the treatment of a man sixty years of age who weighed 220 pounds and suffered seven fractures, three being compound and two comminuted. Slides will show how traction will often secure a reduction in the most widely displaced fragments, and that when union does occur one has a much better chance of securing a good functional result than when an open operation is performed. You will see what a splendid result this man obtained both in the reposition of the fragments as well as in the final functional result.†

WILLIAM DARRACH (New York, N. Y.): In connection with the very useful method which Dr. Allen has described by using traction on bad supracondylar fractures of the elbow, I would emphasize the point that if a satisfactory reduction is not obtained by traction alone within the first twenty-four hours, it is often wise, under a brief anesthetic, to use manipulation in addition to the traction. Many people think that they must treat a fracture by traction or by manipulation but there is really no reason why both methods should not be used on the same patient. I would also like to emphasize that with the traction method, rotary displacement of the distal fragment can be overcome by changing the direction of pull.

If the lateral films show a true lateral view of the lower fragment but the proximal fragment shows a three-quarter or an anteroposterior view, that is, the fish-tail appearance of which Dr. Dunlop spoke, one can be

* Films were shown to show (1) the type of case, (2) the results obtained and (3) the apparatus.

† Dr. Gilcreest presented slides on this case.

sure there is a rotary displacement. With this type of fracture, with rotary displacement, I do not believe that the distal fragment can be controlled as well by the technic Dr. Dunlop brought out as by wire traction. With a wire through the upper ulna and the patient lying prone with the arm vertical, the forearm horizontal, that is, parallel with the bed, the rotation of the lower fragment can be controlled by changing the position of the forearm.

We have learned by experience that it is possible to make several different mistakes in putting a wire through the upper ulna. If it is put too near the tip of the olecranon, it passes through cartilage alone and may pull out. Secondly, as the surface of the ulna is oblique, the wire tends to skid backwards and gets only a thin shell of bone, or even periosteum alone. We have done both of these and had them pull out. This can be avoided if a small incision is made on the ulnar side of the olecranon, the soft tissues crowded forward so as to protect the ulnar nerve and then a large bore needle and used and made to engage in the bone. If the wire is put through the needle, it does not skid over the top. There is less danger of injuring the ulnar nerve if the wire is inserted from within outward rather than from without inward. The last complication we had was to insert the wire too deeply so that when the forearm was pronated it crowded the wire against the radial nerve.

In spite of these various complications we have found wire traction in these difficult supracondylars of great help, especially when there is marked swelling or any interference with the radial pulse. We have used this method in about 15 per cent of over 600 supracondylars and in no instance have we had to divide the fascia in order to relieve tension to avoid ischemic paralysis.

PHILIP D. ALLEN (closing): I believe Dr. Dunlop's remarks regarding Volkmann's ischemic paralysis were most interesting. I believe this method does have a lot to do in preventing those contractures.

In the old days when we used to put them up in flexion and when we got a lot of swelling and were afraid we were going to get a Volkmann's ischemia, we used to forget the reduction and hang them straight up in order to get rid of the edema. We have never on our service had to cut down on any of these in the anticubital fossa.

INTERVERTEBRAL DISKS

PAUL B. MAGNUSON, M.D.
CHICAGO, ILLINOIS

WHENEVER I discuss this subject I feel like paraphrasing Shakespeare: I come not to bury Caesar nor to praise him. I have no quarrel with ruptured intervertebral disks when you can find them and when they are there. I have a lot of quarrel with a diagnosis of rupture of the intervertebral disk made only on the symptoms of pain in the back, referred down the leg and aggravated by sneezing and coughing.

It seems strange that in more than 10,000 dissections of spines reported by Schmorl he found only two instances of rupture of the intervertebral disk posteriorly. However, in more than 15 per cent of this series he found degeneration of the tissues around the lower spine especially, and this involved all the tissues that go to make up this portion of the spine.

If there is any condition in the body that calls for painstaking and repeated examination, not only of the back but of the patient as a whole, before diagnosis is made, it is when pain starts in the lower back, and especially when it is referred to one leg or the other.

When I started thinking about disks there were certain anatomic factors which were not entirely clear in my mind; therefore, I reviewed the anatomic charts of Dr. Callander* and my old friend and chief, Dr. Gwilym Davis, which show certain relations between the nerve roots and the disks that are rather consistent. Incidentally, there are very few findings that are normal, in the sense that they are constant, in the lower spine. What is normal, anyway? That which is normal for one individual is not normal for another. That holds true in the lower back as consistently as it does in the contour of the face. So what is a normal back? I do not know. If a patient has symptoms in the back, we credit them to certain mechanical defects, if we can find such defects; but certainly the *x*-ray does not show more than 20 per cent of the conditions in the lower back that can cause pain in the back or down the leg.

Anatomic study of a cross-section of the spine at the fifth lumbar vertebra shows that the fifth lumbar nerve usually makes

*CALLANDER, C. LATIMER: Surgical Anatomy, Philadelphia and London, 1933, W. B. Saunders Co.

its exit from the dura just above the level of the fourth lumbar disk. This is the rule in each vertebra above this point. The nerve passes downward and outward to enter the foramen. At the point of exit at the fifth lumbar foramen it is well below the disk. It lies immediately in front of the anterior part of the fifth lumbar inferior facet or lumbosacral articulation, just in front of the anterior part of the joint capsule. Entering the vertebra just lateral to the posterior longitudinal ligament is an internal plexus of veins. The posterior longitudinal ligament is a fibrous structure, one of the sturdiest parts of the annulus. It blends with the annulus and forms the posterior wall. The nucleus pulposus is situated just a little anterior to the posterior edge of the vertebral body. The posterior and lateral wall of the neural canal is formed by the ligamentum flavum, which is attached to each vertebral arch above and below. The ligamentum flavum is cupped out at each intervertebral foramen where the nerves exit.

In our investigations we studied ten fresh specimens of spines which had been removed very soon after death and had not been put in formalin. Dr. Larmon, who did this anatomic work, and who incidentally is the first Kemper Fellow in the Surgery of Trauma in the new group of Fellowships at Northwestern University Medical School, injected all these specimens and measured the foramina and the diameter of the nerve before and after injection. He found the average difference between the diameter of the nerve and the diameter of the foramen to be only 1 mm. He could close the foramen and cause pressure on the nerve at its exit, merely by injection of the joint with thorotrast. This does not take into consideration swelling or thickening or induration in an inflamed joint, but merely induced pressure within the joint. It is not inconceivable, therefore, that swelling, thickening or irritation around the joint or the ligamentum flavum could, and in my opinion frequently does, cause pressure on the nerve at its exit.

Willis found marked variation in the normal anatomy of the lower spine, particularly at the lumbosacral junction. These anomalies occurred in 7 per cent of 748 anatomic specimens; and Willis called attention to the fact that they could account for many of the symptoms and combinations of symptoms which occur in the lower back, especially at the fifth lumbar vertebra and lumbosacral junction. Such anomalies may be present, however, without ever causing symptoms, and I had this called to my attention rather

forcibly recently when my father, at the age of eighty-four, sustained a fracture of the fourth lumbar vertebra. The *x*-ray showed the body of the vertebra slipped forward 50 per cent on the first sacral, and yet he had never complained of backache.

Tropism, or an inequality of the angle of articulation of the facets on opposite sides, is seen frequently in the *x*-ray. Some are perpendicular on one side and horizontal on the other, with considerable variation in the angle. With such a condition existing, a patient could have all the symptoms that have been ascribed to rupture of the intervertebral disk. The same symptoms may occur without any radiologic findings as a result of gout, and in my opinion gout is much more frequent in the back than in its traditional site, the great toe. I have seen many patients recover from backache on a régime of proper diet and elimination, with no other treatment. As a matter of fact, two patients who had undergone operation for ruptured nucleus pulposus without relief of symptoms, recovered promptly when put on a proper diet.

The fifth lumbosacral joint and the fourth lumbar vertebra are called upon to bear the entire weight of the body above the pelvis. This means that the cartilage, which is not too thick on the lumbosacral joint, is pressed upon constantly when the body is in the upright position. In addition, in flexion, there is not only pressure on the cartilage but stretch on the ligaments which support the joints. With the wear and tear of life, trauma, cross-strain, infection, or a combination of any or all of these, there is wearing away of the cartilage at the weight-bearing point, exostoses built up around the joint and at the attachments of the ligaments, and degeneration of the other tissues at this point. It is little wonder that we see these degenerative changes in almost any person past the age of fifty who has performed manual labor all his life.

We are all familiar with the history of the patient who, in stooping, performing some action which he may have done thousands of times before, suddenly gets an acute stabbing pain in the back and cannot straighten up. Several weeks or months later he begins to have pain referred down the leg. To me this means there is gradual increase of thickening and pressure around the nerve at its exit from the spine. Only in two cases of exceptionally severe trauma have I seen sciatic pain occur simultaneously with the onset of pain in the back.

We have demonstrated experimentally that arthritis with exostoses can be produced by trauma alone, by weakening the joints of dogs and allowing the animals to exercise. Exostoses form around the edge of the traumatized joint and the cartilage degenerates progressively, due to often repeated slight traumas constantly administered to the poorly supported joint. The cartilage wears away at the point of greatest trauma and exostoses develop at the edge of the joint. Such pathologic changes are commonly seen in the spines of individuals who have performed heavy labor over a long period of time. When the joints become rough they do not glide normally, and the rough margins cause friction to the worn and degenerated cartilage. This interference with smooth motion in the joint can cause catching and stabbing pain with muscle spasm in the back, just as it can in joints elsewhere in the body that are more easily examined; and whether in the knee, elbow, hip, or lumbosacral joint, the degeneration of cartilage shows the same picture.

When these pathologic changes occur in an area well known to be a point of great mechanical stress, as is the lumbosacral junction, there may be marked narrowing of the intervertebral space, associated with collapse of the disk and irritation of the surrounding soft parts and bone. The annulus is pressed backward toward the canal, narrowing its anteroposterior diameter, while the foramen through which the nerve passes is diminished in size. The area of osteosclerosis is more marked at the posterior part of the vertebral body where the greatest weight is borne, that is, the point of greatest pressure.

I do not believe there can be pressure on a nerve root without referred pain. I do believe that if there is rupture of a nucleus there must be some degeneration of the tissues at that point. If there is a ruptured disk, it should be possible to trace the symptoms back to pressure on a nerve root. However, in any case with a typical history of pain in the lower back with subsequent pain referred down the leg, it would appear more logical to institute conservative treatment first; rest, with traction, moderate immobilization and support, then gradually increased exercise, just as we treat other injured joints. If such treatment is not successful, exploration for a ruptured disk is permissible. Whether or not a disk is found, I believe fusion of the spine should be done at the time of operation to insure permanent relief.

DISCUSSION

GILBERT E. HAGGART (Boston, Mass.): Dr. Magnuson's paper was worth coming from Boston to hear.

It has always been my idea that the discusser, if possible, disagreed with the speaker, as this made life more interesting. I greatly regret that I cannot in many instances disagree with Dr. Magnuson, for I am in complete accord with the statement that all patients complaining of low backache deserve a very adequate and complete study, including a blood uric acid test.

There are obviously a great many causes of pain in the low back. Speaking from a practical point of view of treating people with that condition, in my hands at least it often has been very difficult to diagnose. However, in recent years, with knowledge of the intervertebral disc protrusion, I believe in many instances we have achieved result or relief which before that time we did not obtain.

I am also very sure that a great deal of unnecessary surgery has been done in relation to disc protrusions. To my mind the situation is not unlike that era which followed Sir Arbuthnot Lane's introduction of the plate, when there were a large number of plates applied with many very disastrous results.

But I do believe that the disc entity exists with which statement Dr. Magnuson agrees. I do not believe we should operate on patients until they have been studied carefully. If you exhibit a perfectly definite protrusion, especially one which has ruptured the longitudinal ligament, as occurs even if Dr. Schmorl did not find them very often, I believe you can accomplish two results by this surgery: First, remove the protrusion, and hence pressure on the nerve root. Second, take very special care to inspect, by a probe or an appropriately curved instrument, the vertebral canal through which the nerve runs. If there is any question of its inadequacy as regards space, or if there is any undue reaction there in the way of bony osteophytes or proliferative change remove them; in other words, decompress the canal. It is also not to be lost sight of that by removal of the ligamentum flavum the space as a whole, is decompressed.

As to the localization of the pain and its distribution down the leg, the most informative article on this subject that I know of is by Keegan, of Omaha, who investigated a large number of patients later proven to have had a disc protrusion. He went over the cases pre- and postoperatively, and has accurately mapped out the cutaneous distribution of the various lower spinal nerves. To me these data have been extremely helpful, because I do believe that with appropriate study and tests, as for example the leg-raising test and so forth, you can determine if you have enough evidence to warrant the diagnosis of a disc protrusion. If it is a first attack or if

the patient has not experienced an undue degree of disability, it is our routine on the Bone and Joint Service, in the Lahey Clinic, to advise conservative management which comprises bed rest, heat, muscle exercises, and posture training, together with weight reduction when indicated.

At least 50 per cent of these patients are completely relieved of their symptoms by conservative treatment. I have not followed them long enough to know what they will do in the future. The longest follow-up I have on a patient treated like that is about six to eight years. It took me a long time to be able to make the diagnosis. But we are keeping on with it.

When symptoms recur in the individual who exhibits acute complete disability with this very marked muscle spasm, such as was exhibited in the slides, and if in turn studies indicate a general medical situation compatible with major surgery and you do not elicit any other obvious factors that are producing symptoms, and finally if the spinogram reveals evidence of a defect, then I believe surgery is warranted. In those patients in whom the above situation has obtained our results have been good.

I was much impressed by an article by Kelgreen published in Medical Sciences (the volume is dated 1939–1942), wherein the author reports on some experimental work at the University Hospital of London Medical School. He described experiments carried out on himself and his students, injecting simple saline solution into the intraspinous ligaments by means of which he was able to exhibit a localized and comparatively segmental pain distribution, which further amplifies what Dr. Magnuson reparts.

I appreciated hearing this paper, but I simply say that *selected* patients with low back and sciatic pain should be operated upon.

ALEXANDER P. AITKEN (Boston, Mass.): I have certainly enjoyed Dr. Magnuson's paper. It seems now that you may pay your money and take your choice. You may believe either the Chicago School or the Baltimore School. I am more inclined to agree with Dr. Magnuson, but I cannot swallow all he says either.

It has been my fortune, or misfortune, to have the opportunity, within the past three years, to study a large number of back cases manifesting pain of sciatic distribution. Most of these cases have been diagnosed as ruptures of the intervertebral discs and have been operated upon either by neurosurgeons or orthopedists. It was because these patients were not relieved by surgery that they were referred to me for study.

I want to emphasize a point which Dr. Magnuson made, that all cases should be very carefully studied before any operative procedure is entertained. This is particularly true in compensation cases. If a workman has been unrelieved by one operation, he is very reluctant to submit to another. He thus remains on compensation indefinitely, in some states as long as he may live.

I believe Dr. Magnuson is right when he states that the disorder in many of these cases lies in the facets. In those cases which we have re-explored we have not found a recurrent protrusion of the disc, but we have found the facets to be abnormally placed. In some cases the joint surfaces have been widely separated, in others there has been narrowing of the joint space with degeneration of the articular cartilage. All such cases show a good deal of thickening of the capsule. Whether such thickening is sufficient to cause root pain, I do not know. I am inclined to believe with Dr. Magnuson that it does.

One thing I cannot quite understand in Dr. Magnuson's paper is why there should be a delay in the onset of pain in these arthritic joints. The acute pain in an arthritic knee comes when the joint is acutely swollen. If an arthritic interfacet joint should become inflamed, I should think the referred pain would be immediate and not delayed for some months. This is a minor point perhaps.

In those cases in which we have not had an opportunity to re-explore and fuse we have attempted manipulation and radiation. We have used the Jostes method under an anesthetic with some success. Radiation has been of some value but our success has not measured up to the claims of some roentgenologists.

I agree with Dr. Magnuson that we should not be too ready to remove the disc in cases with referred leg pain. The large percentage of such cases do not have ruptured discs. The disorder may be due to chronic strain on abnormally placed facets. When our cases are studied from this point of view, we are more likely to be successful in our handling of the difficult problem.

EDGAR L. GILCREEST (San Francisco, Calif.): It is a trite expression that "A rose by any other name smells just as sweet." Dr. Magnuson has given us a very comprehensive discussion of backache under the title of "intervertebral discs," and I think that you will agree that he showed that most backache is not due to protrusion of discs.

In his discussion of the subject he mentioned some basic things, but I think he overlooked one, and that is that many of these patients with backache can be cured by manipulation. I think a word ought to be said about that, because in a discussion of backache, such as we have had in the last few moments, not a word has been said about manipulation.

We are letting the cults take that over from us, and there are thousands of people today being treated for backache all over this country by pretty competent osteopaths, who also treat, I think, a great many of the doctors in California who sprain their back playing golf.

They go to osteopaths because they do not think any doctor of medicine can treat backache except by operating or strapping their back or prescribing a liniment. They also go to the chiropractors, who do not do the work as well as the osteopaths.

When we see these cultists actually relieving hundreds and thousands of people with backache, we should not any longer ignore the procedure of manipulation simply because these cultists often use it inadvisedly.

I believe there is not one doctor in ten who knows really very much about manipulating the back. I know when I went to medical school I never heard the subject mentioned. I have talked to doctors all over the United States, and I believe I am correct in saying that few have ever considered the subject seriously.

I have found there are two or three manipulations that often may relieve a person with backache who has been for days or weeks listing to one side, and unable to lean over and button his shoes. The procedure which I use briefly is as follows: The patient lies on his back on a narrow, firm table. He is told to relax. The manipulator, standing at the end of the table, grasps in each hand the patient's heel and ankle and slowly and gently rocks, with a rotatory motion, the lower limbs on the pelvis, reassuring the patient and thereby obtaining the relaxation desired. One lower extremity is then allowed to hang over the side of the table and the other is flexed on the pelvis in order to hold the pelvis steady. Pressure is then gently, but firmly, exerted on the limb hanging over the edge of the table for a few minutes, while counterpressure is exerted on the flexed limb. The position of the limbs is then reversed and the maneuver repeated.

The patient is then put on his side with the lower extremity, nearest to the table, extended fully and the other one flexed at the knee. Pressure is exerted downward on the flexed knee while counterpressure is put on the shoulder of the same side so as to obtain a rotation of the spine, clockwise of the pelvis, and counterclockwise of the shoulder. This same maneuver is repeated with the patient on the other side, changing the position of the legs. During this maneuver, which must also be carried out gently but firmly, a definite snap is frequently felt by the patient and may even be audible to bystanders. When this occurs the pain usually ceases instantly, the patient is completely relieved or may feel only a soreness in the low back. The movements of the back immediately become freer, and the patient delights in trying them out, and as soon as he gets off the table will, almost invariably, bend forward, a movement which he could not make previously, to see if he can reach to his shoes.

Another simple and quick manipulation which may work well in some patients who are not too large or heavy is as follows: Stand the patient back-to-back with yourself, and then put your arms under his axillae and lean forward, lifting him up on your back, hyperextending his lumbosacral region, and then suddenly give a hump or jump which will often instantly relieve him.

PAUL B. MAGNUSON (closing): Thank you very much for this interesting discussion. Dr. Aitken thought there was some question as to whether the pressure was due to the vertebrae. Of course we do not know the angle

of the joints, either perpendicularly or laterally, and it is hard to say how much pressure is caused by the joint and how much of the swelling and thickening occurs after induration occurs. In other joints, however, my experience has been that pain occurs as soon as the joint is locked, and swelling follows.

There is nothing new about manipulation. Hippocrates used it and possibly he was not the originator. When I started practice at the Stockyards these workmen were sent in with an acute pain in the back, who had performed the same actions in the same kind of work for twenty years and suddenly had this acute pain. Quite frequently I relieved them by manipulation. After hearing about a complete transverse lesion occurring as a result of manipulation, I got cold feet and decided that something a little less strenuous might work as well. I found that putting the patient to bed with traction applied, giving rest to the joint, gave just as good a result, and I do not think rough manipulation is justified. These tissues, in my opinion, are degenerated, and should be treated with consideration.

We do not know too much about this, anyway. We are working on a theory. These patients do not die, and we do not have an opportunity to do an autopsy and find out what the circumstances were. Until we have a complete history on a case and have a competent examination made prior to autopsy, I do not think we can come to a definite conclusion that any treatment works 100 per cent.

SURGICAL APPROACHES FOR SURGERY OF THE EXTREMITIES

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THE surgical approaches to be described have been used with satisfaction for a number of years by the author and his staff. No originality is claimed for any of them and most of them will be recognized as old standard procedures.

The criteria for a good surgical approach are: (1) It should provide comfortable access to the structures sought for; (2) it should do as little damage as possible; (3) it should pass between rather than through muscles; (4) it should pass these muscles on the side opposite their blood and nerve supply; (5) it should permit actual visualization of important structures or pass a safe distance from them; (6) it should be possible at the close of the operation to restore the disturbed structures to their normal position and have them regain their normal function as quickly as possible.

SHOULDER

The shoulder joint and upper humeral region may be approached from in front, from above, or from behind. The important anatomical barrier is the deltoid muscle and its nerve supply, the axillary or circumflex nerve. The latter is given off from the posterior cord and passes backward through the quadrilateral space behind the surgical neck, entering the deltoid from behind. (Fig. 1.) Any splitting of the deltoid fibers must be limited to the upper 4 cm. as any injury to the nerve fibers will result in permanent atrophy of the portion of the muscle anterior to the incision.

Anterior Approach. If one is interested only in the subdeltoid bursa and the tendons inserting into the tuberosities, this region may be exposed through a vertical incision 5 cm. in length running downward from a point just anterior to the anterolateral margin of the acromion. (Fig. 2.) The separation of the deltoid fibers should be made bluntly from above downward, crowding the nerve fibers downward rather than cutting them. By retracting the muscle and rotating the humerus, most of the tuberosity region may be visualized.

When a freer exposure is necessary, the approach is made between the anterior margin of the deltoid and the adjacent pectoralis major. The cephalic vein marks this interval. (Fig. 3.) It should be

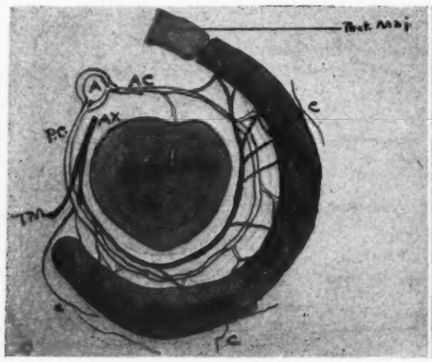


FIG. 1. Relation of circumflex vessels and nerves to humerus. A, axillary artery; AC, anterior circumflex artery; PC, posterior circumflex artery; AX, axillary (circumflex nerve); TM, branch to teres major; C, cutaneous branches of axillary nerve.

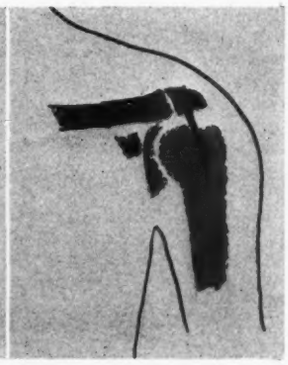


FIG. 2. Exploratory incision. This can later be extended to a transacromial.

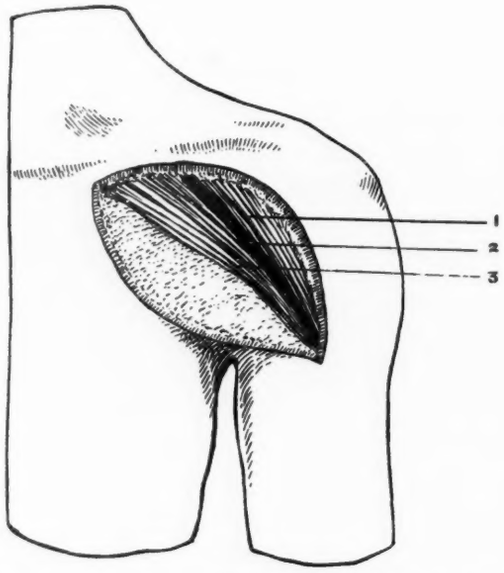


FIG. 3. Anterior approach to shoulder. 1, deltoid; 2, cephalic vein; 3, pectoralis major.

remembered that with the arm abducted to 90 degrees the axillary vessels and brachial plexus pass across the shoulder joint and humeral head. With the arm at the side or with not more than 30

degrees of abduction, these structures lie well below and to the inner side and well out of the way. (Fig. 4.) The skin incision starts 2 cm. to the inner side of the tip of the coracoid, passes outward

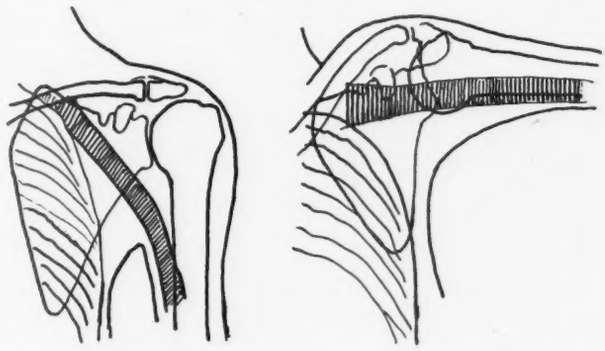


FIG. 4. Relation of axillary vessels and plexus to humeral head in adduction and relation of axillary vessels and plexus to humeral head in abduction.

parallel to the clavicle and then curves downward opposite the acromioclavicular joint for about 7 cm. (Fig. 5.) The flap is dissected up until the cephalic vein is exposed. By retracting the deltoid upward and outward the outer margin of coracobrachialis and short head of the biceps are seen passing vertically downward. Division of the fascia extending outward from these will expose the subscapularis inserting into the lesser tuberosity. (Fig. 6.)

If more room is needed, the anterior deltoid fibers must be divided close to their clavicular attachment and the flap turned outward and downward. (Fig. 7.) The anterior circumflex vessels, passing to the front of the surgical neck should be avoided. More of the axillary space and its contents can be exposed by dividing the coracoid between the attachments of the pectoralis minor and the coracobrachialis and biceps. The coracoid tip and these two latter muscles are then turned downward and inward. Care must be taken not to injure the musculocutaneous nerve and its branch to the coracobrachialis. (Fig. 8.) In closing the wound the base of the coracoid is drilled and the tip held in place by a silk or wire suture; the divided deltoid fibers are reattached to the clavicle and the skin closed.

Posterior Approach. The upper humerus and shoulder can be exposed from behind along the posterior margin of the deltoid. The main structure to be avoided is the axillary or circumflex nerve. This will be found passing from the lower axilla backward between

FIG. 5.

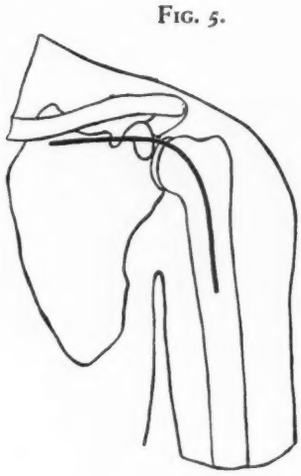
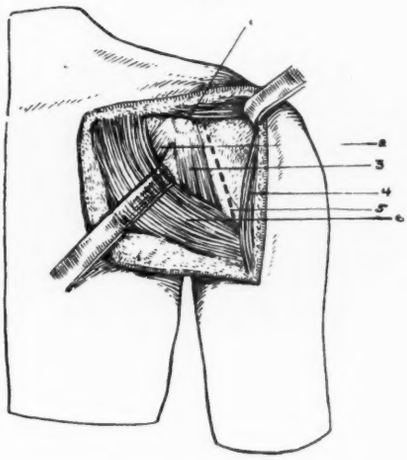
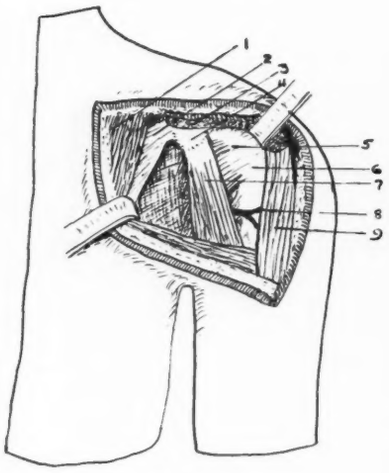


FIG. 6.





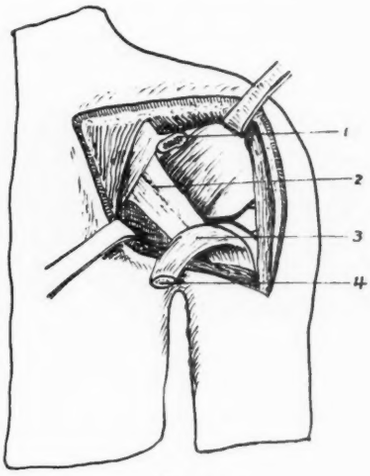


FIG. 7. FIG. 8.

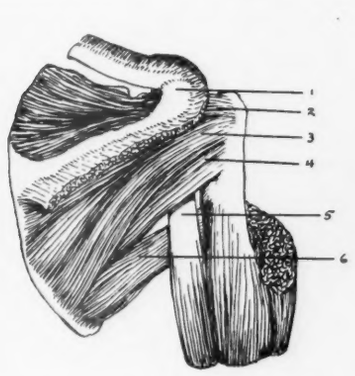
FIG. 5. Anterior approach to shoulder; line of incision.

FIG. 6. Anterior approach to shoulder, deltoid and pectoralis major separated. 1, coracoid; 2, pectoralis minor; 3, coracobrachialis and biceps; 4, deltoid (retracted); 5, line of fascial incision; 6, pectoralis major.

FIG. 7. Anterior shoulder approach; division of anterior fibers of deltoid. 1, pectoralis major; 2, pectoralis minor; 3, cut surface of deltoid; 4, coracoid; 5, subscapularis; 6, capsule over humeral head; 7, coracobrachialis and biceps; 8, anterior circumflex vessels; 9, deltoid.

FIG. 8. Anterior shoulder approach, coracoid divided and coracobrachialis and biceps reflected. 1, cut surface of coracoid; 2, axillary vessels and plexus; 3, coracobrachialis and biceps reflected; 4, tip of coracoid.

the humeral neck and the long head of the triceps, the teres major and minor. The incision follows the deltoid margin and the smaller cutaneous branches of the axillary nerve, encountered as they pierce



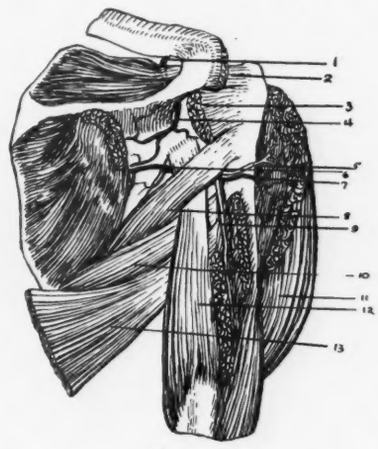


FIG. 9. FIG. 10.

FIG. 9. Deep layer of shoulder muscles from behind, deltoid divided near its origin and removed. 1, acromion; 2, supraspinatus; 3, infraspinatus; 4, teres minor; 5, long head of triceps; 6, teres major.

FIG. 10. Posterior aspect of shoulder showing relation of vessels and nerves. 1, transverse scapular (suprascapular) artery; 2, supraspinatus; 3, infraspinatus (divided); 4, transverse scapular (suprascapular) infraspinal branch; 5, axillary nerve (circumflex); 6, circumflex scapular (dorsalis scapular) artery; 7, posterior circumflex humeri artery; 8, teres minor; 9, radial nerve; 10, teres major; 11, deltoid; 12, triceps, long head; 13, latissimus dorsi.

the deep fascia, will act as a guide to the main nerve trunk. When located this can be retracted upward and inward. This route provides a safe exposure of the upper humerus and inferior part of the joint. This incision usually leaves a very broad scar. (Figs. 9, 10 and 11.)

Transacromial Approach. This modification of the so-called "saber cut" approach gives a free exposure of the upper aspect of the shoulder joint with the attachment of the intrinsic muscles to the tuberosities, without endangering any important nerves or blood vessels. It is useful in cuff tears, complicated fractures of the upper humerus with or without dislocation, and gives room enough to carry out the Nicola procedure. The outer portion of acromion and attached deltoid are reflected outward and downward, exposing the intrinsic shoulder muscles and the upper humerus. (Figs. 12 and 13.) The skin incision (Fig. 14) crosses the acromion in the sagittal plane a short distance mesial to its outer border, passing downward 2 cm. behind and 3 cm. in front of the bone. The acromion is divided

obliquely from the posterolateral angle to a point 2 cm. mesial to its anterolateral corner. Splitting the deltoid fibers in front and behind allows the bone fragment and attached muscle to be retracted

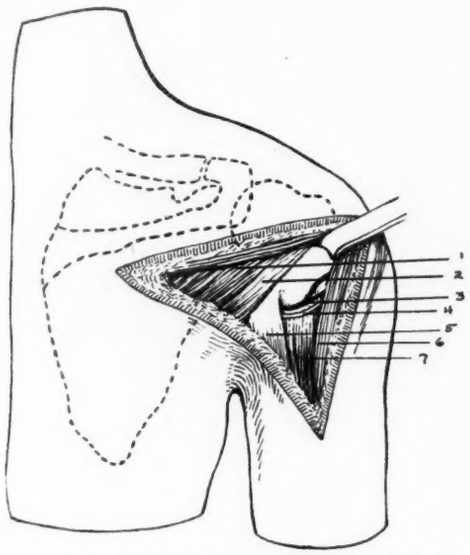


FIG. 11. Posterior shoulder approach. Incision along posterior margin of the deltoid, the latter (No. 6) retracted upward and outward showing underlying structures. 1, infraspinatus; 2, teres minor; 3, posterior circumflex artery; 4, axillary (circumflex) nerve; 5, long head of triceps; 7, outer head of triceps.

outward and downward. (Fig. 15.) In closure, if the bone fragment is excised and the deltoid reattached to the acromion, the convalescent period will be shortened, and active movements may be started earlier than if bony union were required.

ARM

In the upper two-thirds of the arm, all the important vessels and nerves lie in the inner part of the anterior compartment, with the exception of the radial nerve. The latter, with its accompanying blood vessels, passes obliquely downward and outward, lying close to the posterior aspect of humerus between the inner and outer heads of the triceps. The safest route to the humerus passes along the posterior margin of deltoid and either just in front of the lateral intermuscular septum or through the outer fibers of the brachialis muscle. (Figs. 16 and 17.) At the junction of the middle and lower

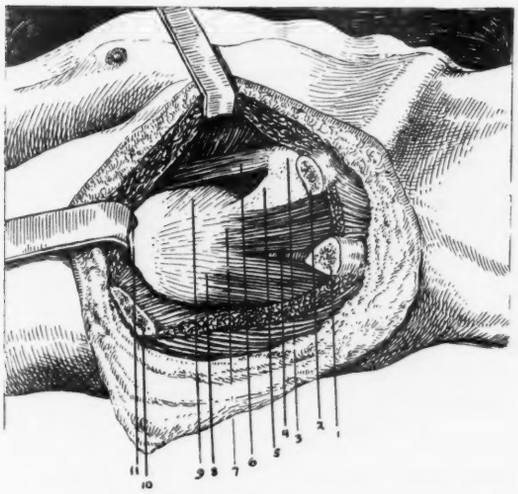


FIG. 12. Dissection of shoulder from above. The outer portion of clavicle, spine of scapula and acromion have been removed, the tip of the the latter and deltoid reflected outward and downward, exposing the roof of the shoulder joint; mid-rotation. 1, stump of spine of scapula; 2, stump of clavicle; 3, coracoid process; 4, transverse scapular artery; 5, coracohumeral ligament; 6, coracobrachialis and biceps; 7, supraspinatus; 8, infraspinatus; 9, subscapularis; 10, tip of acromion; 11, bicipital groove.

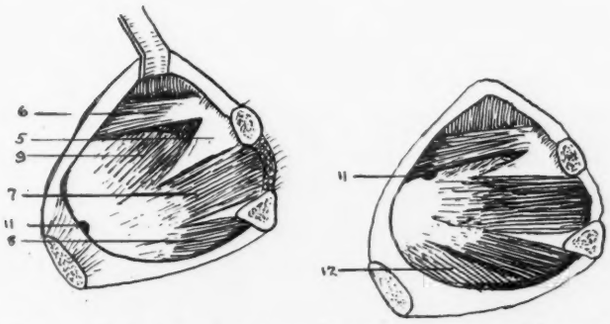


FIG. 13. Relation of cuff muscles in outward and inward rotation of shoulder. 5, coracohumeral ligament; 6, coracobrachialis and biceps; 7, supraspinatus; 8, infraspinatus; 9, subscapularis; 11, bicipital groove; 12, teres minor.

thirds the radial nerve pierces the lateral intermuscular septum to lie deep between the brachialis and brachioradialis muscles. The approach in the lower third of the arm, therefore, should be along

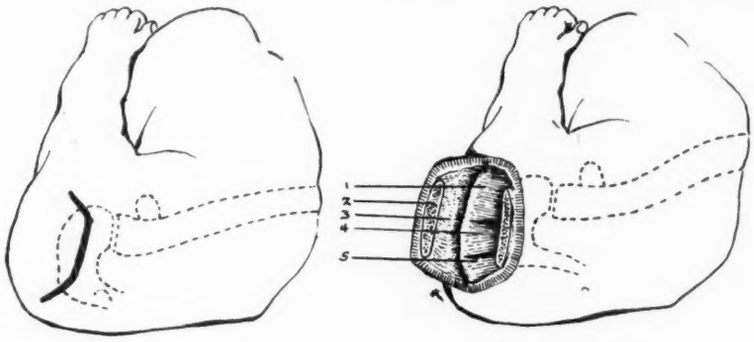


FIG. 14. FIG. 15.

FIG. 14. Transacromial approach to shoulder; skin incision.

FIG. 15. Transacromial shoulder approach. 1, subscapularis; 2, acromion divided and turned outward; 3, deep surface of deltoid; 4, supraspinatus; 5, infraspinatus.

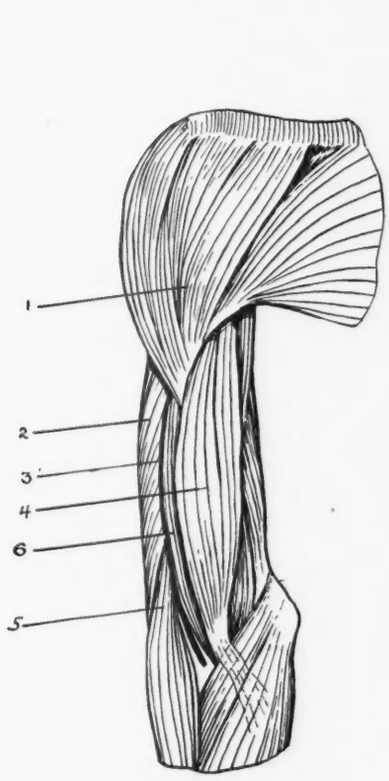
the anterior margin of the latter muscle. In a fracture of the humeral shaft, this route makes it possible to explore the relation of the radial nerve to the ends of the bone. (Fig. 18.)

ELBOW

The elbow region may be explored safely from any direction except the anteromesial where the brachial vessels and the median nerve lie. Vertical and oblique incisions across the fold of the elbow tend to give wide scars which often contract and may interfere with extension. Transverse incisions heal with narrow scars and can be used when a limited exposure is necessary or they can be combined with vertical extensions.

Anterolateral Approach. This route passes between the brachioradialis and the biceps and through the outer fibers of the brachialis. The following structures are encountered: One of the superficial veins, usually the median cephalic (Fig. 19) requiring ligation; the lateral antebrachial cutaneous branch of the musculocutaneous which emerges from the outer margin of the biceps about 5 cm. above the joint line and pierces the deep fascia and runs downward and outward to the forearm (Fig. 20); the anterior radial recurrent vessels will be encountered in the lower part of the wound as they emerge from beneath the outer margin of the pronator teres and require ligation; the radial nerve lying deep in the space between

the brachioradialis and brachialis and passing downward on the latter muscle. As all the branches of the radial nerve pass laterally in this region, if the nerve is identified and the branchialis fibers



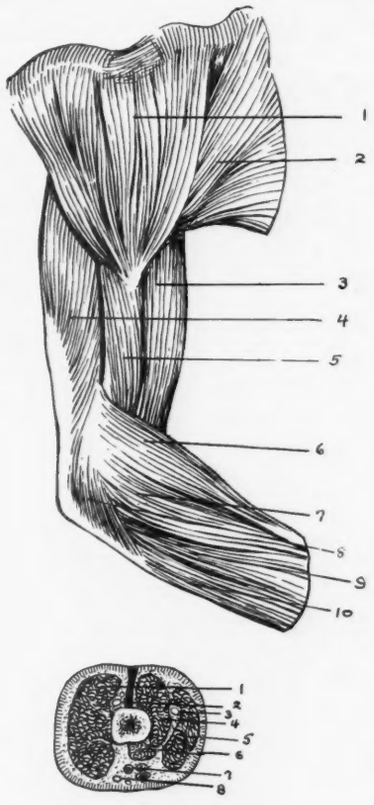


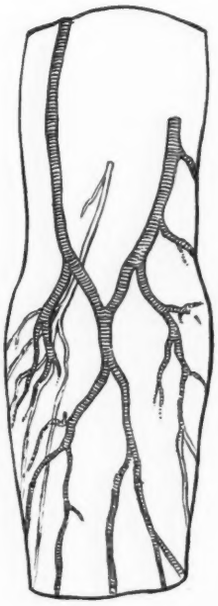
FIG. 16. FIG. 17.

FIG. 16. Anterior aspect of arm. 1, deltoid; 2, triceps; 3, line of incision; 4, biceps; 5, brachioradialis; 6 brachialis.

FIG. 17. Lateral aspect of arm; incision line in black, 1, deltoid; 2, pectoralis major; 3, biceps; 4, triceps; 5, brachialis; 6, brachioradialis; 7, extensor carpi radialis longus; 8, aconeus; 9, extensor carpi radialis brevior; 10, extensor communis digitorum. Cross section of arm, middle third. 1, triceps; 2, radial nerve; 3, musculocutaneous nerve; 4, brachialis; 5, biceps; 6, coracobrachialis; 7, brachial artery; 8, ulnar nerve.

split to the inner side of the nerve, the latter will escape injury. The skin incision should be "step-cut," the upper vertical portion along the margin of the brachioradialis, the horizontal opposite the joint line and again vertically downward. (Fig. 21.) After ligating the vein and retracting the musculocutaneous nerve (Fig. 22) the inner margin of the brachioradialis is freed and the muscle retracted outward until the radial nerve is identified. The latter is followed downward and the anterior radial recurrent vessels divided between

FIG. 18. Cross section of lower third of humerus. 1, brachial veins; 2, biceps; 3, brachial artery; 4, median nerve; 5, basilic vein; 6, medial intermuscular septum; 7, ulnar nerve; 8, triceps; 9, cephalic vein; 10, musculocutaneous nerve; 11, radial nerve; 12, brachioradialis; 13, lateral intermuscular septum; 14, line of incision.



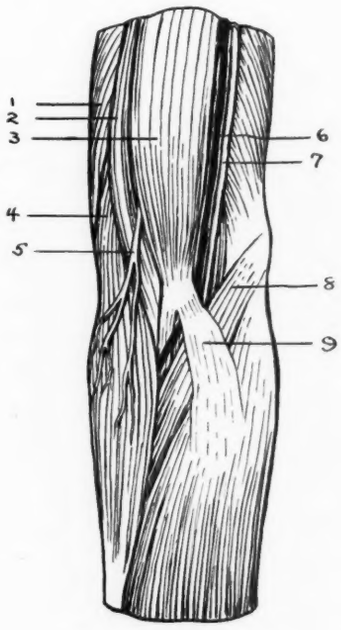


FIG. 19. FIG. 20.

FIG. 19. Elbow, anterior aspect; superficial veins and musculocutaneous nerve.

FIG. 20. Elbow; anterior aspect; 1, triceps; 2, brachialis; 3, biceps; 4, brachioradialis; 5, musculocutaneous nerve; 6, brachial artery; 7, median nerve; 8, pronator teres; 9, lacertus fibrosus.

ligatures. (Fig. 23.) The incision is then deepened through the outer fibers of the brachialis and the joint capsule. (Fig. 24.) In closing, the structures tend to fall into place and only a few sutures are

FIG. 21.

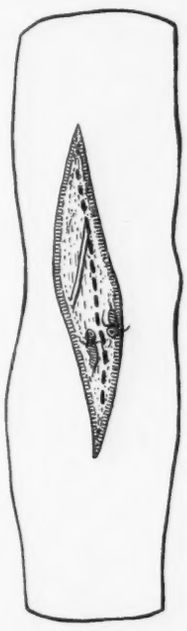


FIG. 22.

FIG. 21. Elbow; anterolateral approach; skin incision.
FIG. 22. Elbow; anterolateral approach showing musculocutaneous nerve and divided superficial vein; dotted line, fascial incision.

required for the capsule and deep fascia. This approach is useful in exploring the front of the elbow joint, removing fragments of radial head which lie in front of the capsule, repairing anterior dislocations of radius, or capitellar or trochlear fractures.

Lateral Approach. The interval between the capitellum and the radial head provides the shortest route to the elbow joint. This is where joint swelling first becomes evident and where aspiration should be carried out. The only intervening structures besides skin, fascia and capsule are the aponeurotic fibers of the extensor muscles attaching to the lateral condyle and the upper fibers of the supinator muscle. (Fig. 25.) One must avoid the dorsal interosseous branch of the radial nerve as it passes obliquely backward lateral to the neck of the radius between the two layers of the supinator. (Fig. 26.) The incision passes from the lateral epicondyle downward in the axis of the forearm. (Fig. 27.) Through this route the radial

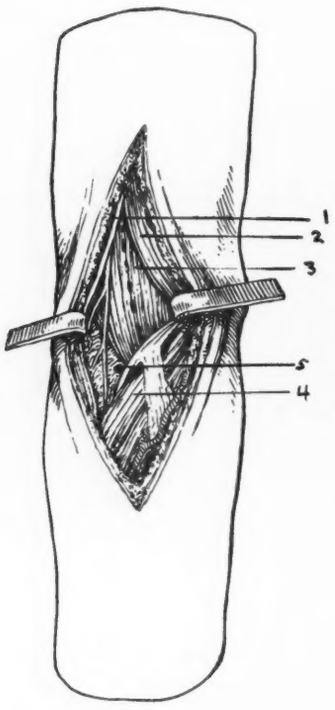


FIG. 23.

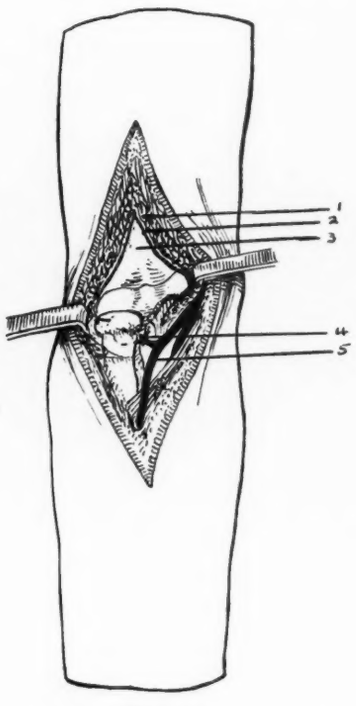


FIG. 24.

FIG. 23. Anterolateral approach. 1, radial nerve; 2, biceps; 3, brachialis; 4, pronator teres; 5, radial recurrent artery.

FIG. 24. Anterolateral approach. 1, brachialis (divided); 2, capsule (divided); 3, humerus; 4, anterior radial recurrent artery (divided); 5, radial artery.

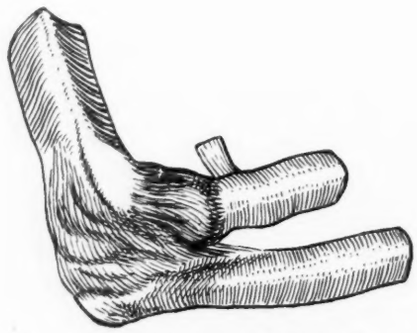


FIG. 25. Lateral aspect of elbow; bones and capsule.

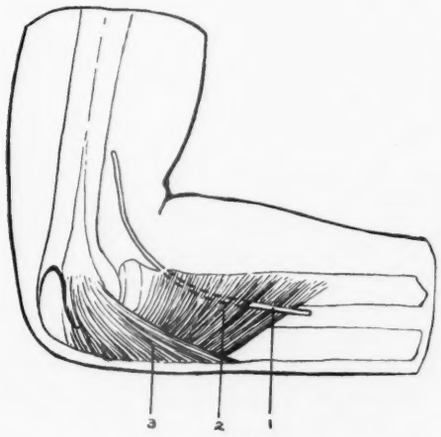


FIG. 26.

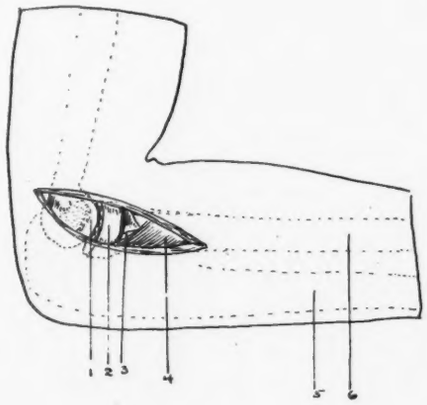


FIG. 27.

FIG. 26. Lateral aspect of elbow. 1, posterior interosseous nerve emerging from between two layers of supinator; 2, supinator; 3, aconeus.

FIG. 27. Lateral approach to elbow. 1, capitellum; 2, radial head; 3, orbicular ligament; 4, supinator; 5, ulna; 6, radius.

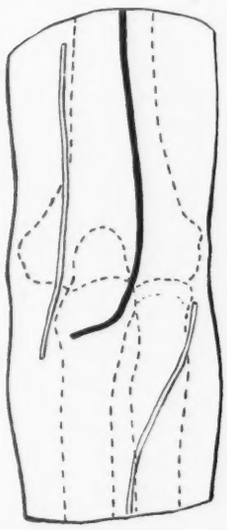


FIG. 28.

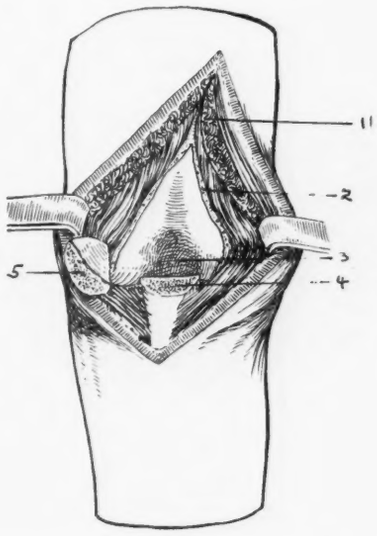


FIG. 29.

FIG. 28. Posterior approach to elbow showing line of incision, ulnar and posterior interosseous nerves.

FIG. 29. Posterior elbow approach. 1, triceps, split and retracted; 2, capsule; 3, olecranon fossa; 4, cut surface of olecranon; 5, tip of olecranon retracted inward.

head can be removed. To replace and fix a fracture of the lateral condyle, the incision should extend a little higher.

Posterior Route. The attachment of the triceps to the olecranon

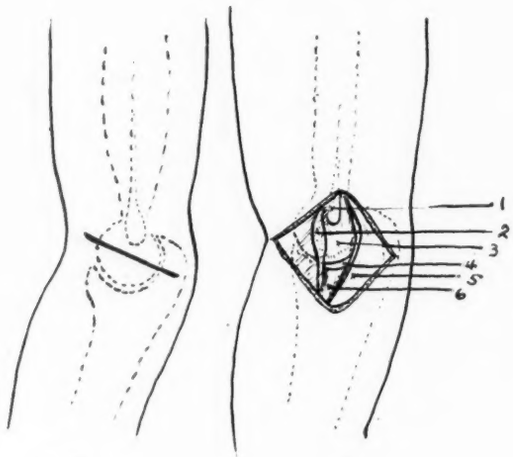


FIG. 30. FIG. 31.

FIG. 30. Mesial approach to elbow; skin incision.

FIG. 31. Mesial approach to elbow; horizontal skin incision, retracted up and down; vertical incision through soft parts. 1, medial epicondyle; 2, pronator and flexor attachments retracted forward; 3, inner surface of trochlea; 4, joint space; 5, dorsal structures covering ulnar nerve; 6, inner surface of ulna.

makes this approach difficult unless the latter is divided and turned to one side. In order to avoid injury to the ulnar nerve as it lies in the groove behind the medial epicondyle, it is better to make the vertical part of the incision along the lateral margin of the olecranon, swinging horizontally inward about 3 cm. below its tip. (Fig. 28.) The bone should be divided opposite the bottom of the greater sigmoid notch. If it is divided from within outward, there is less danger of injuring the ulnar nerve. By reflecting the olecranon and attached triceps inward, a free exposure of the lower humerus is obtained. (Fig. 29.)

Mesial Approach. For fractures of the medial epicondyle or medial condyle, the bone can be exposed by separating the periosteum and origin of the medial collateral ligament, the pronator teres and flexor group from the lower portion of the medial supracondylar ridge and epicondyle in a vertical plane. If the skin is divided in the same line, the scar is apt to widen; so it is better

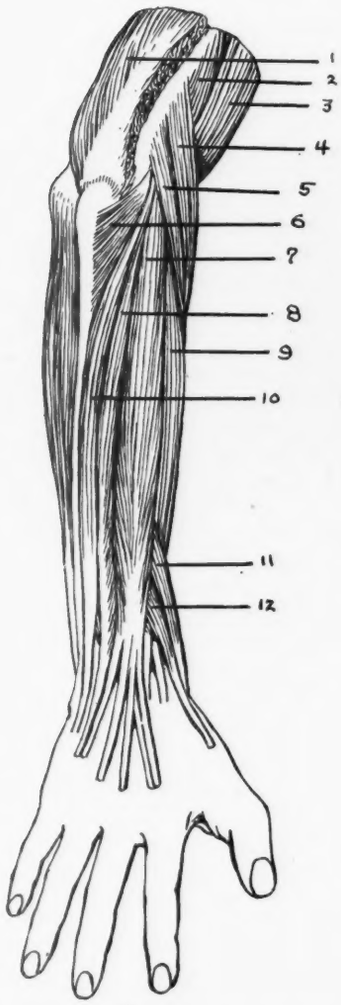


FIG. 32.

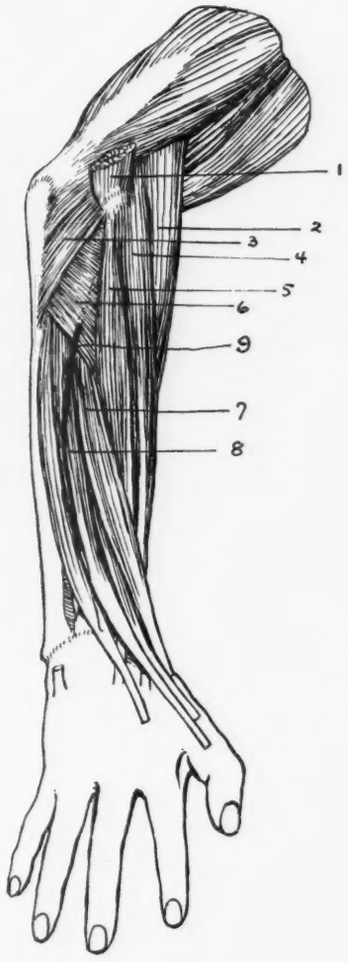


FIG. 33.

FIG. 32. Dorsal aspect of forearm, superficial layer. 1, triceps; 2, brachialis; 3, biceps; 4, brachioradialis; 5, extensor carpi radialis longior; 6, aconeus; 7, extensor communis digitorum; 8, extensor minimi digiti; 9, extensor carpi radialis brevior; 10, extensor carpi ulnaris; 11, abductor longus pollicis; 12, extensor brevis pollicis.

FIG. 33. Dorsal aspect of forearm, deep layer. 1, extensor communis (divided); 2, brachioradialis; 3, aconeus; 4, extensor carpi radialis longior; 5, extensor carpi radialis brevior; 6, supinator; 7, abductor longus pollicis; 8, extensor brevis pollicis; 9, posterior interosseous nerve.

to make a horizontal skin incision with dissection of upper and lower flaps. (Figs. 30 and 31.)

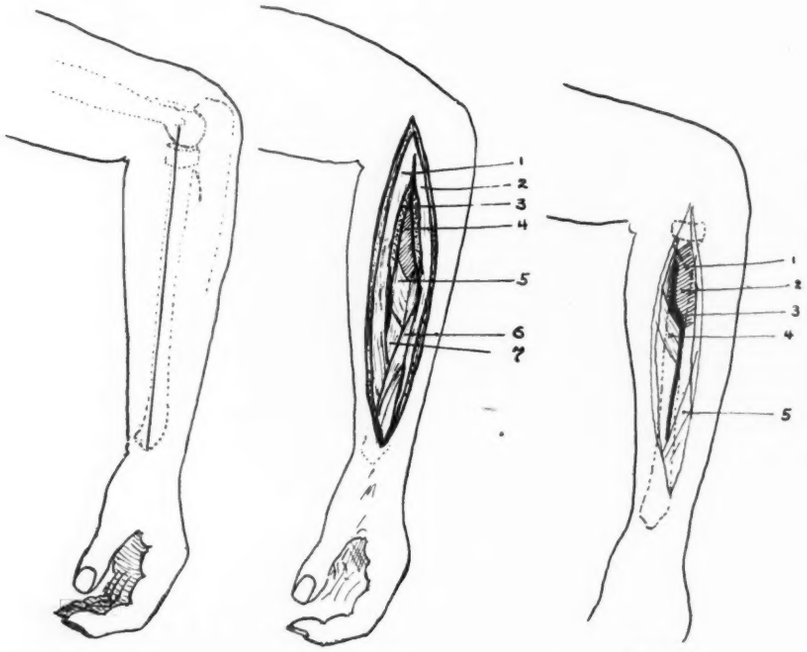


FIG. 34. FIG. 35. FIG. 36.

FIG. 34. Posterolateral approach to radius, route of incision.

FIG. 35. Posterolateral approach to radius. 1, extensor carpi radialis brevior; 2, extensor digitorum communis; 3, extensor carpi radialis brevior stripped from intermuscular septum between it and extensor digitorum communis; 4, supinator; 5, tendon of pronator teres; 6, abductor pollicis longus; 7, radial shaft.

FIG. 36. Posterolateral approach to radius. 1, crossing of posterior interosseous nerve; 2, supinator; 3, line of periosteal incision; 4, pronator teres; 5, abductor pollicis longus.

FOREARM

Ulna. As the dorsal aspect of the ulna is subcutaneous throughout its whole extent, its approach is simple.

Radius, Upper Shaft. The upper two-thirds of the radial shaft is well covered by muscle. (Figs. 32 and 33.) Any anterior approach endangers the blood and nerve supply of the flexor group. Posteriorly, the dorsal interosseous nerve must be avoided. If the interval between the extensor communis digitorum and the extensor carpi radialis brevis is used, no large vessels are encountered; but in the lower part of the incision, the superficial branch of the radial must be avoided as it passes backward from beneath the tendon of

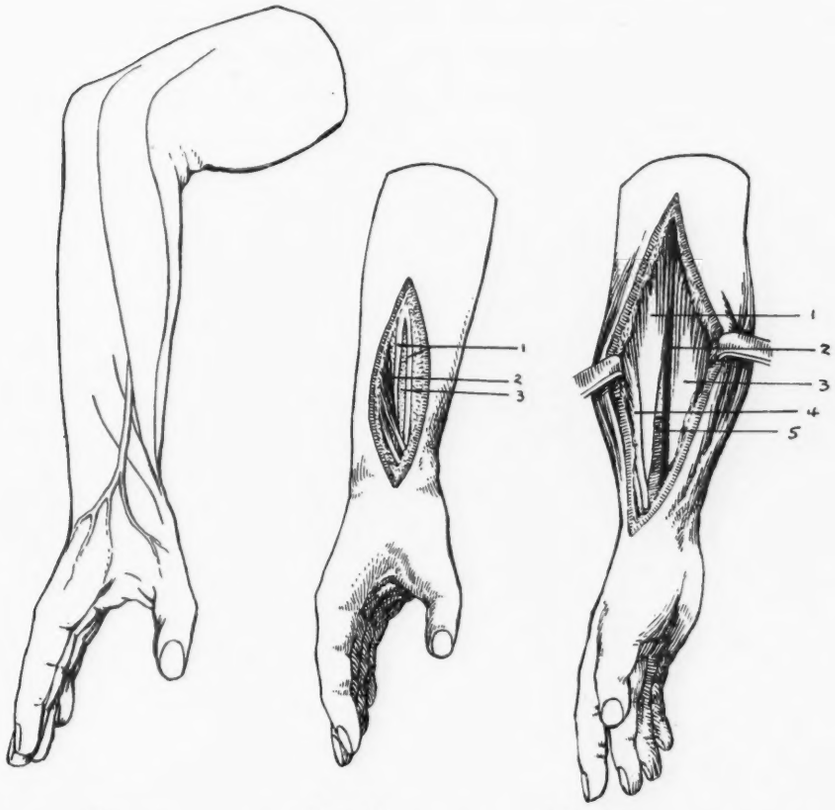


FIG. 37. FIG. 38. FIG. 39.

FIG. 37. Lateral approach to lower radius showing relation of superficial radial nerve to tendons of brachioradialis and abductor pollicis longus.

FIG. 38. Lateral approach to lower radius. 1, split tendon of brachioradialis; 2, abductor pollicis longus; 3, radial shaft.

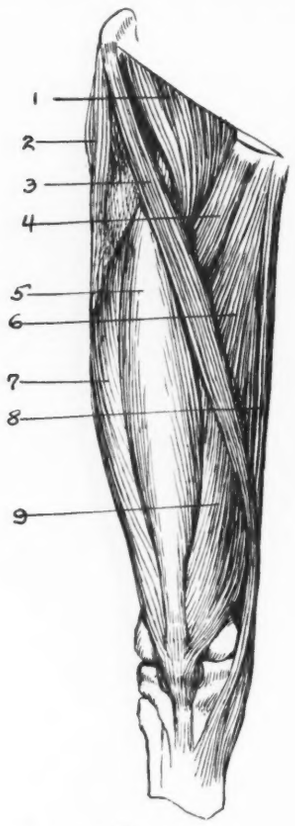
FIG. 39. Lateral approach to lower radius showing relation of radial vessels. 1, brachioradialis; 2, radial vessels; 3, flexor carpi radialis; 4, abductor pollicis longus; 5, pronator quadratus.

FIG. 40. FIG. 41.

FIG. 40. Cross section of mid-thigh.

FIG. 41. Cross section of mid-thigh showing anterolateral and posterolateral routes to femur.

the brachioradialis. With the elbow at right angles and the forearm in mid-pronation an incision made along a line from the lateral epicondyle to the radial styloid will expose the interval between



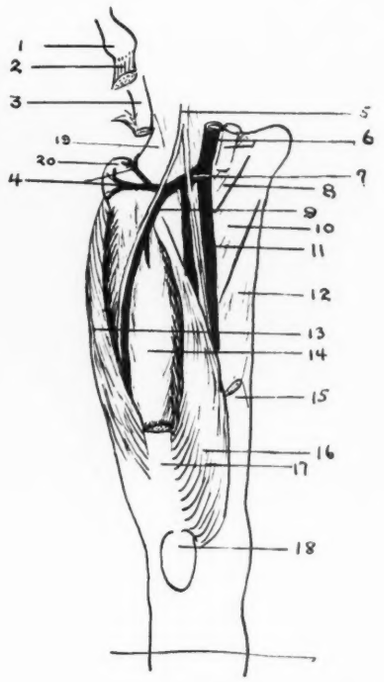


FIG. 42. FIG. 43.

FIG. 42. Anterior femoral region. 1, psoas iliacus; 2, tensor fasciae femoris; 3, sartorius; 4, pectineus; 5, rectus femoris; 6, adductor longus; 7, vastus lateralis; 8, gracilis; 9, vastus medialis.

FIG. 43. Anterolateral approach to femur (rectus, sartorius, tensor and glutei removed). 1, anterior-superior spine of ilium; 2, cut end of sartorius; 3, cut end of rectus; 4, transverse and ascending branches of lateral circumflex artery; 5, anterior femoral nerves; 6, common femoral artery and vein; 7, profunda femoral artery; 8, pectineus; 9, descending branches of lateral circumflex artery; 10, adductor longus; 11, superficial femoral artery; 12, adductor magnus, 13, vastus lateralis; 14, vastus intermedius; 15, stump of sartorius; 16, vastus medialis; 17, stump of rectus; 18, patella; 19, capsule of hip; 20, great trochanter.

these two muscles. (Fig. 34.) The extensor carpi radialis brevis arises in part from the intermuscular septum between it and the extensor communis digitorum and must be stripped from this septum from below upward the desired distance. As the muscles

are retracted, the shiny tendon of the pronator teres will be seen and above this the anterior margin of the supinator. (Fig. 35.) By dividing the fascia over the radial margin of the abductor

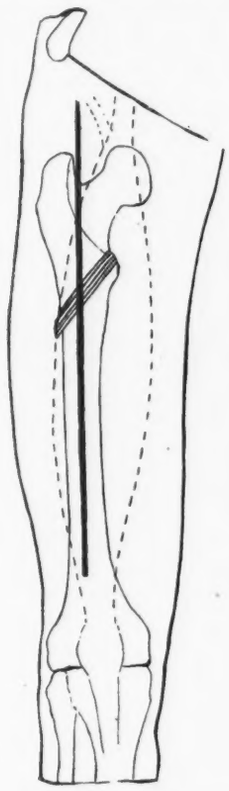


FIG. 44.

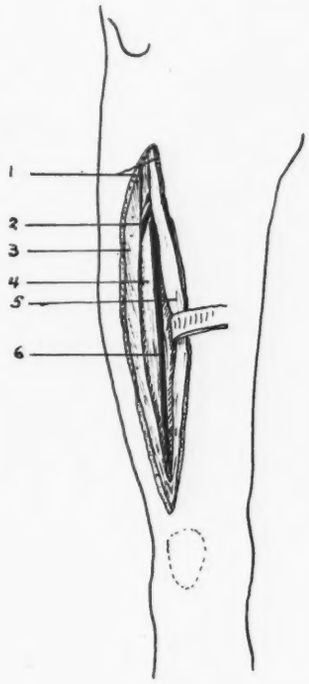


FIG. 45.

FIG. 44. Anterolateral femoral approach, line of skin incision; crossing of neurovascular bundle.

FIG. 45. Anterolateral femoral approach. 1, line of skin incision; 2, crossing of descending branches of lateral circumflex vessels and nerves to vastus lateralis; 3, vastus lateralis; 4, vastus intermedius; 5, rectus femoris retracted inward; 6, line of incision through vastus intermedius.

longus, the latter can be retracted inward to expose the radial shaft below the pronator insertion. (Fig. 36.)

Radius, Lower Extremity. The lower third of the radius is best approached from the radial aspect, avoiding the superficial radial nerve. This emerges from beneath the tendon of the brachioradialis at the junction of the middle and lower thirds and passes vertically downward. (Fig. 37.) The tendon of the abductor longus pollicis and extensor brevis pollicis are loosened and retracted

backward. For the lower shaft one should pass between the tendon of the brachioradialis and those of the two radial carpal extensors. In the lower extremity it is better to split the tendon of the former

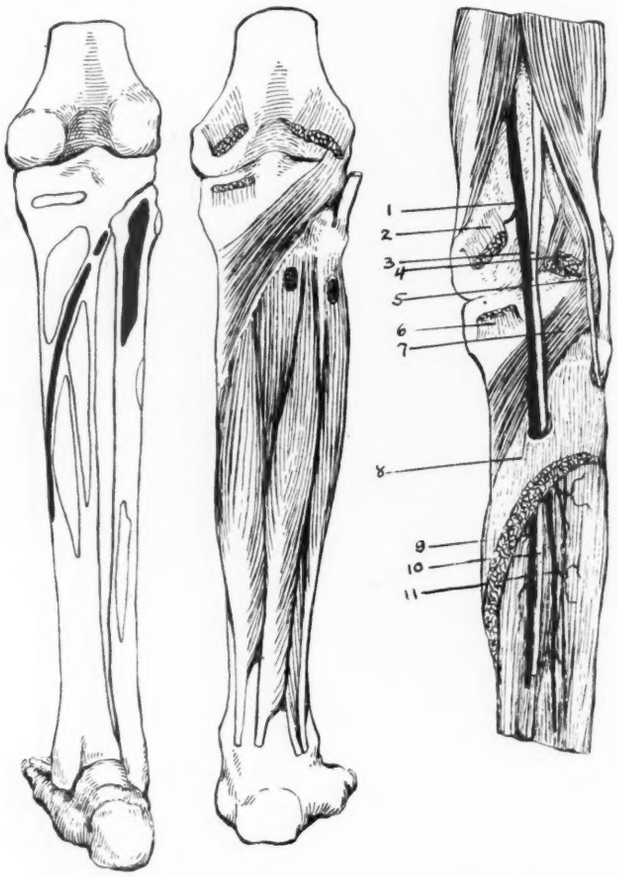


FIG. 46. FIG. 47. FIG. 48.

FIG. 46. Posterior calf showing muscular origins, soleus in black.

FIG. 47. Posterior calf, deep layer.

FIG. 48. Posterior aspect of knee and upper calf. 1, popliteal artery; 2, gastrocnemius, inner head; 3, tibial nerve (internal popliteal); 4, gastrocnemius, outer head; 5, peroneal nerve (external popliteal); 6, insertion of semimembranosus; 7, popliteus; 8, soleus (lower portion removed); 9, posterior tibial artery; 10, posterior tibial nerve; 11, peroneal artery.

as it inserts into the base of the styloid and reflect it with periosteum on either side. (Fig. 38.) A firmer closure can be obtained if this is done In stripping the bone in this region one must avoid the radial vessels which lie close at hand. (Fig. 39.)

SHAFT OF FEMUR

In exposing the femoral shaft, it is important to injure as few blood vessels and nerves as possible. If a direct lateral approach is

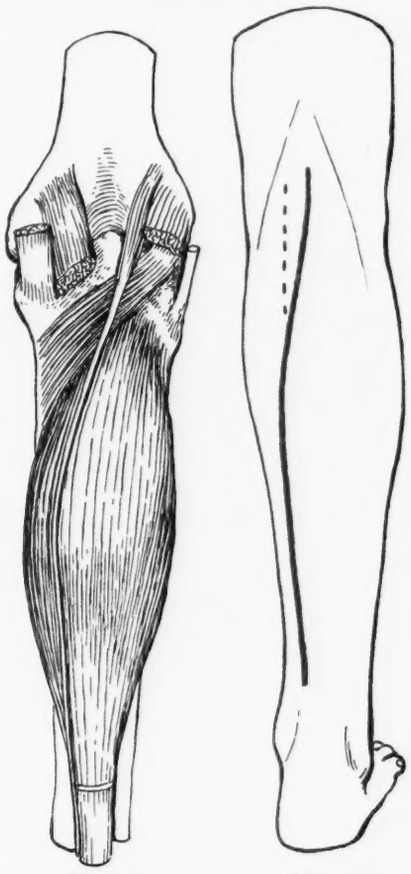


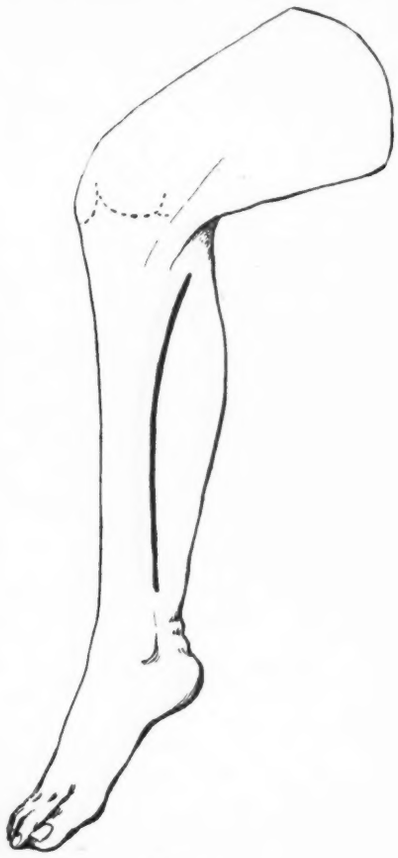
FIG. 49. FIG. 50.

FIG. 49. Posterior calf with gastrocnemius removed, showing popliteus, plantaris, soleus.

FIG. 50. Posterior calf, line of incision.

used there will be a good deal of bleeding and the fibers of the vastus lateralis lying dorsal to the incision will atrophy from injury to their nerve supply. These difficulties can be avoided if the interval between the vastus lateralis and hamstrings is used with the patient lying prone. It is well to keep anterior to the intermuscular septum to avoid the sciatic nerve. (Figs. 40 and 41.) In dealing with fractures, the anterolateral route is more convenient. This passes between the descending branch of the lateral circumflex vessels

on the outer side and the superficial femoral on the inner and between the branches of the anterior femoral nerve. (Fig. 42.) The rectus femoris is freed on its outer margin and retracted inward.



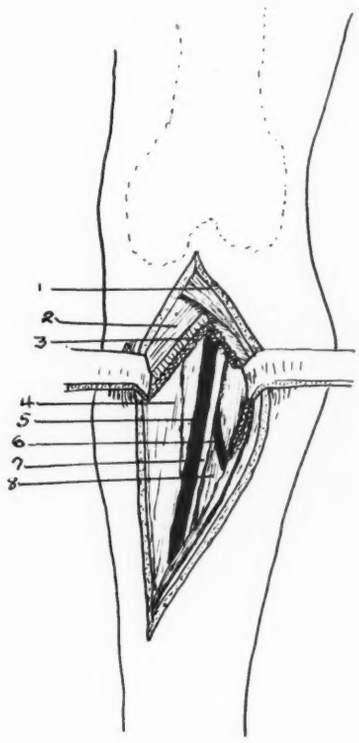


FIG. 51. FIG. 52.

FIG. 51. Posterior calf, line of incision from inner side.

FIG. 52. Approach to posterior tibial vessels. 1, gastrocnemius retracted; 2, popliteus; 3, soleus divided near its origin; 4, flexor digitorum longus; 5, posterior tibial artery; 6, peroneal artery; 7, posterior tibial nerve; 8, tibialis posticus.

The medial aponeurotic margin of the vastus lateralis can be identified and the muscle retracted outward. In the interval between this muscle and the intermedius the large neurovascular bundle of descending lateral circumflex vessels and femoral nerves can be located crossing in front of the femur just below the lesser trochanter. (Fig. 43.) By splitting the intermedius, the femur can be exposed from the crossing of these vessels to the supracondylar region. (Figs. 44 and 45.)

LEG

In penetrating wounds of the calf and injury to the vessels and nerves, a direct posterior approach is difficult and very bloody. The posterior tibial and peroneal vessels together with the tibial nerve lie beneath the fascia which separates the deep muscles from the soleus. By detaching the medial and upper attachments of the latter muscle, with the knee flexed and the foot in plantar flexion the soleus and gastrocnemius can be retracted outward giving free axis to this region. (Figs. 46 to 52.)

DISCUSSION

HENRY C. MARBLE (Boston, Mass.): I recall many years ago, when I was a young surgeon in France, in the next operating room there were other older and younger surgeons. On occasion I was called by the head nurse into the operating room to assist these rather less experienced men, because the wound was wet and because they were not accomplishing what they wanted to accomplish.

I recall then, I being only three decades of age, that the main thing I used to do was to take a knife with me, and would take the approach which they had into the shoulder or into the femur and extend the wound fully its full width upward, and then extend it fully as far below. The resultant exposure was usually about three times as long as the wound which they had. I would then go back to work in my own operating room.

I had quite forgotten that until we were called upon recently to give courses of instruction to young medical officers who were going into the Army. It interested me very much, when I talked with Dr. Darrach, to know that in New York they had much the same experience which we had in Boston, (but up to this time we had not collaborated in our discussions), namely, we bought cadavers and spent a very considerable time in teaching simple anatomical approaches.

Dr. Darrach tells me that in their teaching they utilized somewhere around 40 per cent of their time teaching anatomical approaches. I then thought of the time I spent in teaching anatomic exposures many years ago.

So this is timely and proper. The length of the incision varies with the age of the surgeon. It should vary inversely, but actually it varies directly. Dr. Darrach has shown you exposures, and they are well done. I want to review them very briefly, in a very personal way.

I like his anterior approach to the shoulder. He follows the delta pectoral groove, which is the new expression, then cuts across the outer end of the acromion and lays the wound wide open. His incision is fully six inches long and is dry and clean. That gives a proper exposure to the shoulder.

He showed you the posterior approach. I must confess I have never used that approach but once, and at that time I used it purely on theoretical grounds to drain pus in the shoulder joint which, fortunately, we rarely have.

Dr. Darrach uses that same approach for draining cysts and for getting at the upper end of the humerus. That approach through the back, in which he goes through the teres minor, which is lower, is a nice approach but rarely used.

His approach to the midarm you should all remember, mainly because of the length of his drawings.

The approach to the lower arm I vary a bit. I teach my students that in the posterior approach to the elbow the first thing to do is to isolate the ulna nerve, dissect it free and take it out of the ulna groove, and to have it free. I have found that this is a safer approach. Later when the surgeon reaches the back of the elbow, if the nerve is taken out of the groove and displaced medially, it is best open to injury. So I always say, locate the ulna nerve first; dissect it down until it is passed the elbow, and then take it to one side. That dissection always carries you to the back of the elbow.

The dissections at the head of the radius from the back I vary a bit from the pictures Dr. Darrach has shown, and I make the incision along the end of the ulna. I take the anconeus muscle and reflect it outward. I then expose the radial ulna joint and approach the head of the radius from the back. It is much the same incision, but I am a little more timid than Dr. Darrach is, and I expose it further from the radial nerve which is there open to injury.

The anterior approach I am glad he showed you, because it is an excellent approach. It is used first, in approaching injuries to the front, to the antecubital space.

For instance, in Volkmann's contracture, there are masses of blood under the deep fascia of the forearm which must be approached quickly. I vary the incision very little. He makes an "L" shaped incision but I make the approach on the inner side of the upper arm, across the antecubital space, squarely across, and continue the incision on the outside. I then have the large vessels of the upper arm under view, I have the antecubital space in full view, which can be dissected under the fascia, and by exposing the supinator we re-expose the radial nerve, reflect it outward, and take it promptly down to the whole antecubital space. I cut the little vessels in front of the head of the radius and the latter is then fully exposed. That is an incision which even a junior surgeon in a hospital should know and use in an emergency.

From there I will jump to incisions in the lower arm. I follow them exactly as Dr. Darrach does.

In the lower leg there is one approach which he did not use, and which I daresay he would have gladly added had time permitted, and that is the posterior approach to the hip joint. I think in wartime every surgeon should familiarize himself with the posterior approach to the hip joint. Infections of the hip joint in war are common. This joint needs prompt and complete drainage, and it is best drained through the posterior approach.

I do not know who described it, but I think it was a Belgian; Dr. Darrach will tell you later. It is done through the back, and the main thing is that the sciatic nerve is found and retracted mesially, and the back of the hip joint is exposed through the rear, so the drainage from the hip joint shall be dependent and complete rather than through the front.

I think incisions which I like best are those of Dr. Darrach. They are anterolateral rather than lateral, and go in through the muscle exactly as he does it; and I am sure you will all agree that Dr. Darrach and I advocate strongly a dry route. I like that word. We love a "dry" route. I do not know how you spell "route," but we like it.

There is another thing which I want to say in just a word, and it is that we should familiarize ourselves with the lateral drainage of the knee joint for infection, lateral incisions with the synovia brought out to the skin so that we may have complete drainage of infections of the knee joint.

In the lower leg Dr. Darrach did not say anything about approaches, but I will say that Dr. Fred Cotton taught me one should never approach the front of the lower leg through a straight incision. Someone might say now we are going to have a "dry route" and we are going to be "crooked."

JOHN CALDWELL (Cincinnati, Ohio): I think this paper alone is worth the trip here.

In some operations on the forearm, the posterior approach, will be found very helpful. I like to drape an arm with sterile stockingette, roll it into a doughnut shape, then autoclave it and roll that on the arm from beyond the fingers to the axilla. It covers the arm completely so it is not possible to get under the drapery.

If you have to make an incision for the olecranon, the head of the radius or the outer side of the arm, instead of putting the patient's arm out on the arm board you simply throw the arm across the chest. Take the excess of the stockingette and tie a weight on it (we are accustomed to use a weighted speculum). Let that hang over the side of the patient's body. The arm will be held secure in that position, and you can use the intern and the assistant for some other purpose than to hold the arm in one position all the time.

WILLIAM DARRACH (closing): There is one approach I did not have time to give, which I should like to put on the screen because I think it may come in handy.

One of the greatest troubles we had a few years ago was in what we call the tight calf; that is, wounds of the calf from small bits of hardware, from which there was so much hemorrhage that the calf acted as if it had been blown up with a tire pump. If you went in through the middle of the gastrocnemius and soleus, there was so much old blood and new blood it was pretty hard to see where you were, or pick up the wounded posterior to the vessels or serve. There is a trick to that.*

* Dr. Darrach presented three additional slides with the following explanation: (1) The deep layer of the muscles with a hole for the anterior and tibial vessels to go through, and the posterior tibial nerve and artery and the perineal on top of those muscles covered over by fascia. (2) The popliteal artery coming down through the bridge of soleus muscle, with the posterior tibial, perineal and popliteal vessels. This showed the soleus in place, with the plantaris showing. The attachment of this soleus muscle is along the oblique line of the tibia. This showed the line of incision along the margin of the soleus on the inner side. The soleus is attached to the postero-internal margin of the tibia and is not attached below. It goes obliquely across the oblique line of the tibia. If you start down here and separate the soleus from the deep plane, you get in that interval, and with plantar flexion of the foot and knee, they can be reflected outward. Soleus and gastrocnemius muscles can be lifted up and you come right down on the deep compartment. (3) The deep compartment; this is the plantaris. You get free access to the posterior tibial and peroneal vessels. In that way you can tend to any hemorrhage or injury to the nerve with a dry route.

TREATMENT OF THE PATIENT WITH SPINAL CORD INJURY

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THAT injury to neural structures within the spinal canal may result in one of the greatest of human calamaties is incontrovertible. Methods to obtain the maximum restoration of lost functions are, however, subjects of much dispute. What to do about the numerous disabling effects of such an injury constitutes the subject of this paper. The opinions expressed are the result of personal observations upon sixty-three patients with traumatic injury to the intraspinal neural structures seen during the last seven years. Two of these patients gave clinical evidence of injury to cervical nerve roots only. Neurological examinations revealed signs which indicated damage to the spinal cord or cauda equina in all others. On the basis of time elapsed from injury to examination by me, the sixty-three cases could be separated into two groups. There were thirty-three acute conditions of the spinal cord. The earliest any of the patients in the acute series was examined following injury was one hour while thirteen days was the greatest length of time which elapsed between injury and examination. Thirty cases were classified as chronic; the time interval from injury to examination ranged from one month to fifteen years. This latter group of cases is included in the study, for even though the initial treatment was not under my supervision I had the opportunity of evaluating the treatment which had been carried out by others during the acute stages. I performed laminectomy for decompression of the cord upon nine patients classified as acute and upon two classified as chronic. In addition, seven others in the chronic group had been operated upon by other surgeons before I saw them.

Initial Treatment and Examination. Careful handling of the patient with spinal cord injury to prevent further damage to the cord is obvious. It has been suggested[9] that patients with cervical spinal cord injuries be transported in the face-down position, the argument being that this position forces the patient to keep his neck in

hyperextension and facilitates drainage of vomitus and secretions from the throat. If the patient is placed in this position, great care should be employed to prevent turning of the head to the side.

FIG. 1. Schrieber's pneumatic collar for stabilization of the cervical spine (from Schreiber).

Better still in cases of cervical spine injury is the application at the scene of the accident of Schreiber's pneumatic collar. (Fig. 1.) This ingenious device can be deflated when not in use and, therefore, requires little storage space. When inflated and applied it holds the neck rigidly in hyperextension, thus preventing motion and further damage to the cervical cord. As soon as possible after general shock has been controlled a neurological examination should be done. A neurological examination performed early is important since any change in neurological signs may influence one's decision regarding operation.

Details of the symptomatology produced by lesions at various levels will not be presented since this paper deals principally with methods of treatment. In case there is associated bone damage, the site of injury can usually be determined by discoloration, swell-

ing, acute tenderness, and many times deformity over the point of fracture. When the patient's condition permits, roentgenograms of the spine should be taken, keeping in mind that severe cord damage may occur even though roentgenographic evidence of bony abnormality is absent. A spinal puncture is done to determine whether there is blood in the spinal fluid and whether block in the cerebrospinal fluid pathway is present. The amount of blood and degree of block are not necessarily proportional to the degree of loss of neurological function. Complete and permanent interruption of nerve impulses from levels above the site of injury have been seen with no blood in the spinal fluid and no block. One must be on guard for hysterical paralysis. One patient whom I frequently see has had no less than five hospital admissions with apparent paralysis of the legs and complete loss of sensation from the iliac crests down following minor falls. A few days rest always results in complete restoration of function and return to work. Normal reflexes, lack of disturbance of bladder function, and a tight anal sphincter usually point to the true nature of the condition.

Laminectomy for Decompression of the Spinal Cord or Cauda Equina. Shock combated and examinations completed, the surgeon is faced with a most difficult question, namely, whether to decompress the damaged area of the spinal cord. Some surgeons answer the question easily by operating upon none. Some assume the "nothing to lose" attitude and advise operation on all. Others operate if there is a cerebrospinal fluid block and refrain from operation if there is no block. It has never seemed to me that the question can be answered as easily as that. I believe that laminectomy for decompression of the spinal cord is indicated under the following conditions: (1) Presence of neurological signs indicating that the cord lesion is progressing; (2) incomplete cord lesion with evidence of pressure on the cord as indicated by roentgenogram or spinal fluid block; (3) demonstration that the spinal fluid pathway which was open following injury is becoming blocked.

The above criteria have, in my opinion, been listed in the order of their importance. Few will argue against operation when the first situation is present. In the face of progressive neurological signs certainly the spinal cord should be explored. The second criteria is applicable to injuries in the dorsal and lumbar areas but not applicable to a cervical spine injury. Usually pressure upon the cervical cord can better be relieved by traction with the Crutchfield

tongs than by operation. I agree with Munro and Wegner[10] in their statement that patients with cervical cord injury should not be operated upon in the first few days after the accident. By the application of traction rather than resorting to surgery Munro and Wegner have been able to reduce their mortality for this type of injury by 30 per cent. If there is an incomplete cervical cord lesion and the spinal fluid block persists after an adequate trial with traction, decompression of the cord is then justifiable. I present the third criteria with some doubt in mind. Mayfield and Cazan were convinced "that the result of the Queckenstedt test should not influence one appreciably in selecting cases for laminectomy." However, I doubt that few surgeons could resist the temptation to operate when repeated spinal punctures showed a progressive blocking of the spinal fluid pathway. That operation under such circumstances may not bring improvement is demonstrated by the following case:

CASE 1. Mr. D. A. C., aged twenty-nine, was caught between a car and a truck while riding a motorcycle on October 30, 1943. He sustained a back injury and his legs were immediately paralyzed. One hour after injury examination revealed a complete loss of motor power and sensation in the lower extremities and roentgenograms showed a crushing fracture of the twelfth dorsal vertebra with no apparent bony encroachment on the canal. Spinal puncture immediately after admission to the hospital revealed clear cerebrospinal fluid with no cerebrospinal fluid block on jugular compression. Spinal puncture was repeated on November 2, 1943, and this time there was no rise of cerebrospinal fluid pressure on jugular compression. On November 3rd, a third spinal puncture again showed a complete block. At operation on November 4th, slight pressure was found on the anterior side of the cord due to mild angulation of the spine. The cord was slightly injected but appeared grossly in good condition. A catheter passed up and down the spinal canal met no obstruction. Since the cord appeared almost normal it was hoped that function would return but seven months have elapsed since injury and there has been practically no improvement.

In this case approximately thirty-six hours elapsed between the demonstration of a complete cerebrospinal fluid block and operation. Perhaps the operation should have been done earlier. The only purpose a laminectomy can accomplish is to relieve pressure on the cord. Therefore, when dealing with dorsal or lumbar injuries, the quicker the operation is done the better, provided the patient's general condition will permit surgery.

One must exercise great care while performing a laminectomy upon a patient with spinal cord injury. The following case illustrates the point. This patient fulfilled the requirements of the second indication for laminectomy and we, therefore, believed that she should be operated upon. Following surgery we regretted our decision.

CASE II. Miss M. L. J., aged eleven, had a convulsion on March 11, 1943. Following the convulsion she developed slight loss of motor power in the lower extremities but there was no complete paralysis of any muscle group. Touch and pain sensations were normal throughout the body. The abdominal reflexes were absent. The Babinski, Oppenheim, Gordon, and Schaeffer reflexes were bilaterally positive. Roentgenograms of the dorsal spine revealed compression fracture of the seventh dorsal vertebra. An attempt was made to improve the alignment of the vertebrae by manipulation and traction. Block in the cerebrospinal fluid pathway persisted and operation was advised. The operation was performed on April 7, 1943, with extreme care lest the cord be further traumatized. The cord was found riding over an angulation in the vertebral column opposite the body of the seventh dorsal vertebra. There was pulsation above the point of angulation but none below. When the dura was opened the edges had a slight tendency to retract laterally. The cord appeared normal. The dura was easily closed and a spinal fusion performed. After the patient awakened from the anesthetic sufficiently well to co-operate, it was discovered that she had a complete loss of muscle power in her lower extremities and a decrease in sensation as high as the eighth or ninth dorsal segment. She was taken back to the operating room and the wound reopened. A small bone chip was resting on the dura covering the cord. This was removed and the wound closed. Following reopening of the wound the condition of the patient's lower extremities improved gradually but she never did regain as much motion as she had before surgery.

Pressure from the bone chip may have been responsible for the further loss of function but I am inclined to believe that opening and closing the dura was a more likely cause. In partial lesions of the spinal cord the dura should not be opened unless there is a definite intradural hematoma which requires evacuation. This is particularly true when the dura is under slight tension.

Reduction of Vertebral Dislocation and Stabilization of the Spine. Fracture, dislocation, or fracture-dislocation present the additional problem of reduction, realignment, and stabilization of the vertebrae. The site of fracture will largely determine the method. If there is bony damage with or without neural involvement in the cervical

region, the best method of reduction is by traction with the Crutchfield tongs. One should not be content with simply reducing the cervical dislocation; once reduction has been obtained the neck must

FIG. 2. Case III. Roentgenogram of the cervical spine taken the day following injury. The arrow points to a small chip fracture of the inferior articular process of the fifth cervical vertebra.

FIG. 3. Case III. Roentgenogram of the cervical spine taken two months following injury. There is now a marked forward dislocation of the fifth on the sixth cervical vertebra.

be immobilized for a period of five or six months to prevent redislocation. The following case history illustrates this point:

CASE III. Mr. J. M., aged seventeen, was in an automobile accident on August 9, 1939, at which time he sustained a head injury and was rendered unconscious. When examined approximately twelve hours following the accident the patient was mentally confused. He had a large scalp laceration and bruises about the head. He moved all four extremities. Sensory examination was not possible in his confused mental state. The right Babinski reflex was positive, the left negative. While the examiner was palpating the back of the patient's neck there was an audible pop. Spinal fluid examination revealed a slightly bloody fluid. The dynamics were normal. Roentgenograms of the cervical spine (Fig. 2) showed an excellent alignment of the cervical vertebrae, the only abnormality being

a small chip fracture of the inferior articular process of the fifth cervical vertebra. During the next few days the patient remained mentally confused and difficult to handle. When he became mentally clear, approximately a week following the accident, he complained of slight numbness of the hands. The numbness subsided and he was dismissed from the hospital three weeks after injury. The patient was next seen on October 10th, two months following injury, at which time he came to the office complaining of stiffness in his neck and inability to retract his head as far as usual. Roentgenograms of the cervical spine showed a marked forward dislocation of the fifth cervical vertebra on the sixth. (Fig. 3.) With the redislocation no new neurological signs had developed. The patient was advised to return to the hospital for application of traction but treatment was refused.

Obviously the patient sustained a fracture-dislocation of the cervical vertebrae at the time of his injury which was accidentally reduced by the examiner. When the roentgenograms taken the day following injury indicated normal alignment of the vertebrae, attention was subsequently turned entirely toward the cerebral injury. Measures should, of course, have been taken to stabilize the cervical spine before he was dismissed from the hospital.

When accompanied by neural injury reduction of a fracture in the dorsal or lumbar spine may be accomplished by gradual hyperextension. If the injury is in the dorsal region, the patient's position in bed is reversed, that is, his head is placed at the foot of the bed and his back is placed across the convex surface which is formed when the knee rest is elevated. Gradually the convexity of the bed can be increased until reduction is accomplished. If the fracture is in the lumbar area there may not be room enough between the elevated portion of the bed and the foot of the bed to accommodate the patient's upper torso, head, and neck. In such a case hyperextension is accomplished by placing a blanket roll underneath the mattress to form the convexity of the bed. If articular processes are locked so that reduction by hyperextension is not possible, an operation with unlocking of the processes as advocated by Barber becomes necessary. Once reduction has been accomplished, a plaster of Paris jacket to hold the position might seem desirable but is definitely contraindicated in complete transverse lesions of the cord or cauda equina because of the danger of bedsores.

Following laminectomy for decompression of the cord one must be particularly careful to provide adequate support for the back

before the patient is allowed to sit up, for in these cases the ligaments which have been torn and the articular facets which may have been fractured are still further weakened by the laminectomy. The following is an illustrative case:

FIG. 4. Case IV. Lateral roentgenogram of spine taken before laminectomy. There is compression fracture of the twelfth dorsal vertebra.

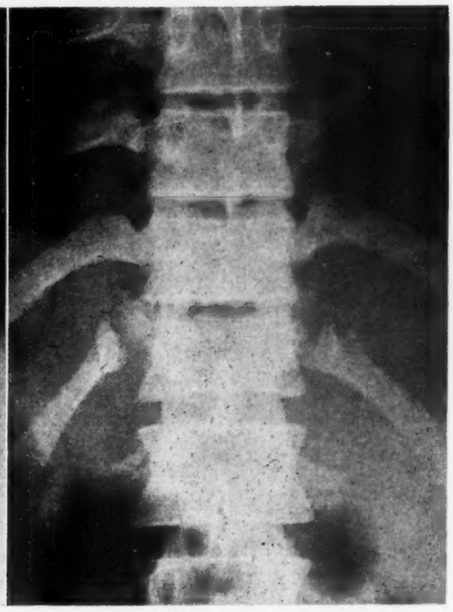

FIG. 5. Case IV. Anteroposterior roentgenogram of spine taken before laminectomy.

CASE IV. Mr. W. N. W., aged twenty-eight, injured his back in an automobile accident on May 2, 1943, and was immediately paralyzed from the waist down. Roentgenograms showed a fracture of the body of the twelfth dorsal vertebra. (Figs. 4 and 5.) A laminectomy was done. The dura was found to be torn and the spinal cord opposite the twelfth dorsal vertebra completely destroyed. The patient was kept flat in bed during the six weeks which he remained in the hospital. Because of his complete sensory paralysis from the umbilicus down he was not placed in a cast nor was he provided with any type of metal back brace. He wished to return home and was allowed to do so. He was seen on January 15, 1944, eight and one-half months after injury, when he returned complaining of pain in his back. Roentgenograms (Figs. 6 and 7) revealed marked displacement of the eleventh dorsal vertebra on the twelfth.

This patient should have remained flat in bed for approximately three months. If roentgenograms then showed adequate bone repair,

he could have been provided with some type of back brace and allowed up. In some of these cases spinal fusion may be desirable but I do not believe that fusion should be done at the time of the

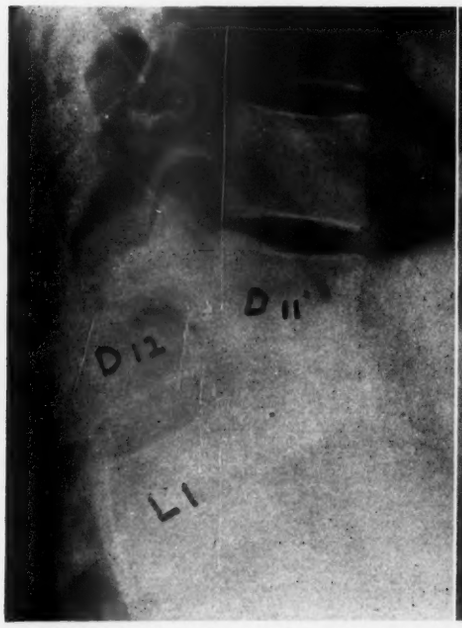

FIG. 6. Case IV. Lateral roentgenogram of spine taken eight and one-half months after laminectomy. There is marked anterior displacement of the eleventh dorsal on the twelfth.

FIG. 7. Anteroposterior roentgenogram of the spine taken at the same time as one shown in Figure 6.

laminectomy. Shortly after injury when the laminectomy is done the tissues are usually so hemorrhagic and torn that spinal fusion would be difficult and too time-consuming.

General Care of the Patient. Every precaution must be taken to prevent bedsores. In my experience the best type of bed is an air mattress. Bradford frames and boards under the bed not only are unnecessary but are actually to be condemned. The air mattress must be inspected at least twice daily to be certain that it is adequately inflated. The only bedsore I have ever seen develop while the patient was on an air mattress resulted from the mattress being insufficiently inflated to keep the hip off the hard bed underneath. Pillows must be placed under the calves of the legs to prevent sores from developing on the ankles and heels. The prevention of footdrop is best accomplished in the following manner: Shave the lower legs, put on a pair of women's silk or thin cotton stockings as high as

the knee and apply a coat of shellac, which sticks the stocking to the leg. Enough of the toe of the stocking should be left projecting beyond the patient's toes so a cord can be tied about it. The cords

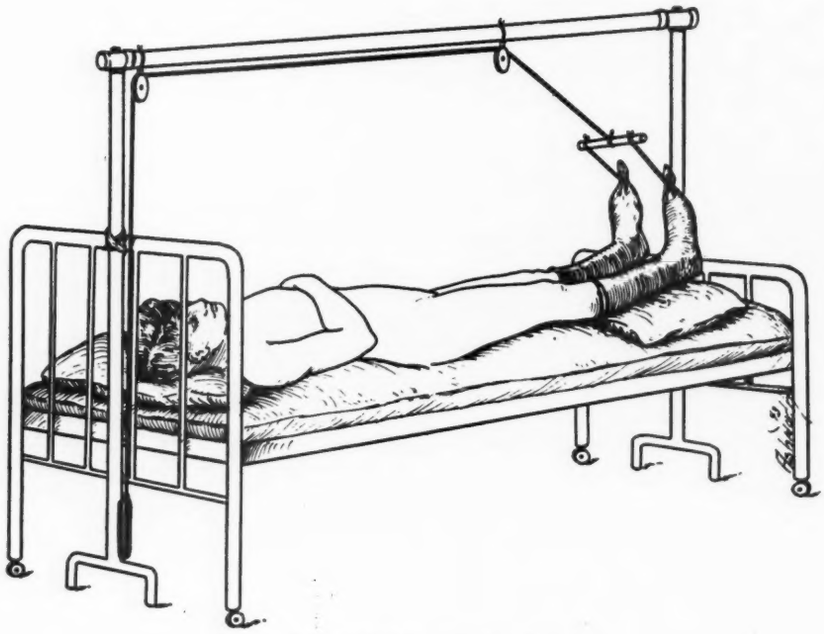

FIG. 8. Method of preventing footdrop.

from the toes of the stockings are attached to a crossbar from which another cord passes up over a pulley on an overhead frame. (Fig. 8.) Weights at the head of the bed keep the feet in dorsiflexion. The patient should be turned in bed every two hours. While the patient is on his side or abdomen the cords to the toes of the stockings can be released. A cradle is necessary to prevent bed covers from resting on the toes. The patient's skin should be gently massaged every three or four hours and passive exercises given the paralyzed extremities. In case a reddened area appears on the skin it should be painted with tincture of benzoin.

Care of Paralyzed Bladder and Bowel.—The following methods have been employed in caring for the acute neurogenic bladder: (1) Non-interference with distention and overflow, (2) manual expression of urine until "automatic" bladder develops, (3) intermittent catheterization, (4) continuous drainage through an indwelling catheter directly into waste bottle, (5) continuous drainage through indwelling catheter with closed irrigator system or

tidal wave apparatus, (6) suprapubic cystotomy, and (7) perineal urethrostomy.

The method of non-interference with distention and overflow should not be used except for very short periods of time when other facilities are lacking, for respiratory and cardiac action may be embarrassed and a bladder so overdistended may not regain its tone.

I have not used manual expression of the urine because adequately trained personnel who can be depended upon to carry out such a maneuver carefully has usually been lacking. Also when this procedure is employed there is a possibility of rupturing the bladder[2] and the wet bed which is usually present makes the occurrence of bedsores likely.

Intermittent catheterization is to be condemned because of trauma to the urethra and introduction of infection into the bladder. Continuous drainage with an indwelling catheter directly into a waste bottle has all the disadvantages of the inlying catheter and none of the advantages of the tidal wave apparatus.

As soon as possible after the patient's arrival in the hospital a tidal wave apparatus is attached to an indwelling catheter in the bladder. I have usually used the apparatus as described by Munro[8] or as modified by Hesser, even though it is recognized that an indwelling catheter may produce urethritis, balanitis, and epididymitis. Another distinct disadvantage of this method is that for a tidal wave apparatus to function properly someone who understands its operation must check it frequently. If this type of drainage is to be used, the following suggestions are made: (1) The use of a Foley catheter so that all bands encircling and constricting the penis may be eliminated; (2) a catheter small enough to allow urethral secretions to escape around it; (3) twice daily manual irrigation of the bladder with boric acid to be certain the bladder is washed out; (4) removal and resterilization of the whole apparatus once a week; (5) the administration of small doses of urinary antiseptics such as methenamine or mandelic acid, continuously given over a long period of time.

A method of bladder drainage which is very satisfactory and deserves more widespread use than it generally has been accorded is suprapubic cystotomy. This method of drainage is very easy to institute through a small suprapubic incision. The indications for its use are (1) old or very ill patients, (2) marked urinary tract

infection, (3) lack of adequate personnel which prevents careful checking on tidal wave apparatuses, (4) inability to tolerate a urethral catheter and (5) transference of patients from one hospital to another which requires a period of several days. Hinman in discussing the problem among soldiers goes so far as to state that he believes a suprapubic cystotomy should be done at the outset of acute retention when the injury is severe, provided it will be days or weeks before the soldier reaches a place where good management will be given.

I have had no experience with perineal urethrostomy as advocated by Lewis. It is claimed that this method is advantageous because the patient can lie on his abdomen part of the time and drainage is better than with a suprapubic tube. One wonders whether the disadvantages, namely, that the catheter passes through the posterior urethra and that for the average physician the insertion of the catheter would be more difficult than performing suprapubic cystotomy, would not outweigh the advantages.

As time goes on the bladder will either recover or become a chronic neurogenic bladder. In the latter case, if the cord has been injured above the conus the bladder will be governed by a simple spinal reflex. Stretching of the bladder wall is the stimulus for bladder contraction and evacuation. The patient can usually adapt himself fairly satisfactorily to this type of bladder activity, but if the contractions are too frequent and the patient dislikes an incontinence bag, he may be more comfortable with permanent suprapubic drainage. If the injury is in the region of the conus or cauda equina, the bladder has no spinal reflex activity and high residual with dribbling incontinence may result. With this type of bladder three measures are available which may aid evacuation; (1) Evacuation may be accomplished by periodic manual suprapubic pressure with straining. (2) In those patients in whom the internal sphincter is spastic, transurethral resection of the internal sphincter is indicated. (3) Finally, a certain number of patients may require permanent suprapubic drainage.

Following a spinal cord injury the patient may have fecal incontinence, but severe constipation is usual. Cathartics should be avoided and an enema given every second day. A rectal examination should be done at least once a week to check for fecal impaction.

Rehabilitation of the Patient. Life for most patients following spinal cord injury is extremely difficult and every available measure

must be taken to make them more comfortable. Massage, warm baths, and underwater exercises should be administered. In some cases the reflex activity of the spastic limbs is such that massage cannot be administered. If the extremities become too spastic, the patient may be more comfortable following intraspinal section of the motor roots which supply the affected muscles. The orthopedic surgeon may aid greatly by stabilization of joints, transplantation or lengthening of tendons and application of braces. Some of these patients present the problem of nerve root pain. Cutting specific sensory roots may bring relief but frequently cordotomy (section of the anterolateral spinothalamic tracts) is preferable.

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DISCUSSION

Harry E. Mock (Chicago, Ill.): Lacking the opportunity of reading Dr. Raaf's very excellent paper beforehand, I am limiting my discussion to the expression of certain personal opinions derived from the treatment of the average number of cord injuries coming to the hands of the surgeon with a fairly extensive traumatic service.

Back injuries of all descriptions are scattered throughout the land. In my experience less than 2 per cent of these back injuries give signs of cord injury. Considering the country as a whole the general physicians and surgeons located in the County seats and the nearby towns see just as many and probably more cases of cord injuries than do the neurosurgeons in the great medical centers. The picture presented by immediate paralysis

from the neck or waist downward in a healthy man or woman who has just sustained an accident is an overwhelming catastrophe. There are problems which must be met immediately by the physician or surgeon first seeing the case if the patient is to survive or is ever to walk again. The essayist has portrayed these steps of management so excellently that repetition is superfluous. However, there are certain points that are controversial or have not been sufficiently stressed. Otherwise, we would not see so many of these patients going practically untreated.

If the paralysis develops immediately following the injury and is complete and corresponds to that segment of the cord adjacent to the fracture or dislocation in the spine, one is justified in assuming that the cord has been injured. The *x*-ray will show the presence of the fracture or dislocation but it does not reveal the amount of compression or the extent of compression of the cord by displaced fragments. A spinal puncture with clear or bloody fluid obtained or with a Queckenstedt test for a block positive will not show the extent of cord injury. In such cases I believe it is logical to assume that the cord may be crushed or transversely severed or it may be severely compressed by a depressed arch or other fractured fragment. If the first situation exists, the case is hopeless so far as the paralysis is concerned; but if the second situation only is present, relief of this bony pressure on the cord may partially, although seldom completely, cure the paralysis. Again, the earlier this mechanical constriction of the cord can be removed, the better chance has the patient to recover from his paralysis. Therefore, the only logical procedure is to do a laminectomy, call it an exploratory laminectomy, to see if early relief from cord compression cannot be obtained. The longer such compression remains on the cord, the greater the degenerative reaction in the neural tissue.

In my opinion, this is the view of the majority of general surgeons, familiar with major trauma cases, especially interested in the surgery of trauma. It is not the view held by many neurosurgeons who in recent years have been preaching delay in laminectomy especially if a spinal block is not demonstrated.

If the paralysis develops slowly over a period of minutes or hours following a back trauma, it is logical to assume that concussion or contusion of the cord with edema or a hemorrhage is the condition present rather than pressure from a bony fragment. Bear in mind that this delayed paralysis may be due to some accident following lifting of the patient onto the *x*-ray table or similar movement. Ruling this out, then one is justified in delaying laminectomy; for in the majority of these cases, the edema will subside, the hemorrhage will absorb and recovery will follow within a few weeks or months.

Every patient with paralysis, whether subjected to laminectomy or not, should be placed upon an air mattress just as early as possible. Every

effort must be made to avoid decubitous ulcers. Within the year I have seen a patient completely paralyzed due to a fractured eighth dorsal vertebra, encased in a body cast. When the cast was removed three weeks later, large decubitous ulcers were present over the knuckle of the fracture, the sacrum and both ilia. For the same reason plaster or mechanical splints to the lower extremities to prevent foot drop or faulty positions should be avoided. Muslin hammocks, ropes, pulleys and weights and frequent exercises should be used to control this situation.

When an indwelling catheter for tidal drainage or otherwise is used, every precaution must be taken to avoid infection. The catheter should be self-retaining by means of a balloon or a mushroom on the bladder end, rather than retained by dirty adhesive applied about the glans penis. If cystitis develops and recurring attacks of ascending infection occur, cystotomy is the safest method of caring for the bladder.

Finally, physical therapy started early and persisted in for months and even for two or three years will eventually reward the surgeon and the patient with a certain amount of function in many of these cases.

E. P. PALMER (Phoenix, Ariz.): Any patient who has been involved in a serious accident should be treated as though he had an injury of the cord. The unconscious patient cannot tell you that he cannot feel or that he cannot move his extremities, yet he may have a serious involvement of the cord.

Therefore, that patient should be handled with care, the same as a patient is handled who is known to have an involvement of the cord, transported carefully to the hospital and treated as though he had an injury of the cord, until it is proved otherwise.

I cannot agree with the theory that these patients must have a delay of weeks or months before they are operated upon. Years ago I carried out a series of experiments on animals and we proved that compression of the cord carried on over six hours resulted in permanent injury. There is no regeneration of spinal cord tissue. When it is destroyed it does not regenerate.

Therefore, if you are going to have beneficial results after injury to the cord, and an operation is indicated, the operation should be done within the six-hour period. If you wait thirty-six hours, as Dr. Raaf did, or wait three weeks to six months, before operating upon these patients, you are going to have fatal results.

JOHN CALDWELL (Cincinnati, Ohio): A few cases follow that illustrate some of the points that have been mentioned:

We have observed at the Cincinnati General Hospital a series of six patients who have had spinal injuries with cord lesions, in which the *x*-rays have been entirely negative; they have shown nothing at all. Four of those patients had complete transverse lesions, yet the *x*-ray picture was entirely negative, and the picture was taken right away.

After death necropsy of these four patients showed there had been a complete transection of the cord by displacement of a vertebra, but in the handling of the patients bringing them in, there had been immediate reduction.

That, to my mind answers fairly conclusively this question of immediate laminectomy to relieve pressure. There is no surgeon who gives quite as prompt relief as that. These patients are just dragged out from a wrecked automobile or moved about in an ambulance and have a displacement of the vertebra, which has been so completely reduced that the *x*-ray is entirely negative.

Two patients survived, one with almost complete symptoms. He was emaciated to a shadow; he could not lift his arms. He would stand up and walk with a shuffling gait if he was helped to his feet. He could not feed himself. He was in a most pitiable condition. That was present three years later.

The other patient, a lineman, twenty-nine years ago, fell out of a tree and had an incomplete lesion, probably a traumatic hematomyelia. He had dissociation of sensation. Some years later he made a fairly complete recovery and could get about. In fact, he went back to work as a lineman, but the disassociation of the sensation persisted to such an extent that three years later he stood in front of a great fire and burned both of his shins without knowing it. His functional recovery, however, was fairly good.

The following is another case illustrating a different phase: A young woman struck by a rapidly moving automobile had a crushed chest, a lateral dislocation of the sixth and seventh dorsal segment, a bad head injury and terrific shock. She was brought in in such shape that there was nothing to do; we could not even take an *x*-ray nor do a spinal puncture.

Upon examination it was found that one leg was completely out, and within a few hours the other leg's motion and sensation disappeared. She rapidly developed bladder symptoms.

On account of her general condition nothing at all could be done for her. The position of the vertebra showed that there was urgent demand for an attempt to reduce the displacement, but her condition would not permit that. Before the week was out she developed a complete lobar pneumonia from which she convalesced. At the end of that time an attempt was made at reduction of her spinal deformity, and nothing at all was accomplished. We planned a late laminectomy with her, but before we got started on it she began to improve.

The final result was that at the end of three months or so she regained complete bladder function; she had quite a good gait finally with slight spasticity. Several years later she could dance and do practically everything she wanted to do, and she finished a university course. If I had done a

laminectomy on her, I think I would have thought I had accomplished quite a surgical triumph.

JOHN RAAF (closing): My plea is for the development of some rationale for laminectomy in these cases. I wish I could develop the attitude that all patients should be immediately operated upon because this attitude would take a terrific strain off my judgment.

However, I do not believe all patients with spinal cord injury should be indiscriminately subjected to surgery. As I stated previously, Munro found that in cervical cord injuries conservative treatment netted 30 per cent lower mortality.

In the dorsal and lumbar regions if there is evidence of an incomplete lesion of the spinal cord, and if a block is present, I believe operation should be carried out.

PENICILLIN THERAPY*

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THE discovery of penicillin is usually described as accidental. But this is not entirely true. For fifty years prior to Dr. Alexander Fleming's recognition of the possible significance of the lytic effect of a contaminant mold on an agar culture of staphylococci, many bacteriologists had observed this phenomenon. In 1900, Emmerich[1] isolated an antibacterial substance from Bacillus pyocyaneus which was later found to check the growth of diphtheria bacilli *in vitro* and to exert a favorable action on the clinical disease. However, the true importance of this phenomenon of antibiosis was overlooked for the time being.

In September, 1928, while examining some agar plates of staphlycoccus, Dr. Fleming, (a bacteriologist at Oxford University) noted complete inhibition of growth in the neighborhood of a contaminant mold which he identified as Penicillium of the Notatum group.[2] Had it not been for Dr. Fleming's many years of interest and research in antibacterial agents, it is possible that the significance of this observation would have been overlooked. Following it up he found that the mold, grown on the surface of nutrient broth, produced in the broth a powerful antibacterial substance. By 1932,[3] he had demonstrated its action *in vitro* against Streptococci, Staphylocci, Pneumococci and Corynebacterium diphtheriae and had shown it to be non-toxic for animals and non-irritating to the human conjuctiva. He called the substance Penicillin and suggested its use locally in clinical infections caused by the above organisms.

Strangely enough these suggestions were not followed up until after Dubos in 1939[4] published his observations on the antibacterial effect against Gram-positive cocci of an extract of a soil bacillus. This work led to the development of tyrothricin and gramicidin and stimulated Dr. H. W. Florey, also of Oxford, to re-investigate penicillin and work out methods for its production and purification

* From the Department of Medicine, Wesley Memorial Hospital and Northwestern University, Medical School, Chicago. Part of the Penicillin used on patients discussed in this paper was furnished by the Committee on Chemotherapeutics and Other Agents of the National Research Council and part by the Penicillin Research Committee of Northwestern University Medical School.

in order to make further clinical application possible. By 1941, he had accumulated enough data on its potential clinical usefulness to enable him, during a visit to the United States, to interest the National Research Council and the Department of Agriculture to undertake the studies of the mold's growth characteristics and possibilities for large scale propagation. To Dr. Coghill and Dr. Mayer of the Northern Regional Research Laboratory at Peoria belong much of the credit for this work. To the pharmaceutical houses, and manufacturers of biologicals and chemicals belong the credit for the actual attempts at mass production.

At first it was believed that the mold could be satisfactorily grown only in small amounts of nutrient media. This resulted in the type of production in which the mold is grown in individual flasks containing not more than two liters of media each. Recovery of 5,000 to 10,000 units per flask was considered a good yield. Obviously it was physically impossible to produce enough by this method to supply both military and civilian requirements. Intensive efforts on the part of mycologists, chemists and engineers connected with fermentation and commercial chemical industries resulted in the perfection of methods of growing the mold in submerged cultures in huge tanks of broth or on bran. The increased production made possible by such methods is responsible for the civilian availability of penicillin today.

From 1941 to May 1st of this year clinical and laboratory research on penicillin was under the direction of the committee on Drugs and Therapeutics of the National Research Council. As indications of specific clinical usefulness developed the military forces requisitioned all but a very small amount of the total production. That which was left was allocated to selected investigators throughout the country and from their studies have come our present knowledge of dosage, methods of administration, rate of absorption and excretion and clinical applications of the drug. As experience expands this knowledge will be extended and our present concepts may be modified. However, enough definite information is at hand to remind us that it is not a cure-all and the present tendency on the part of some clinicians to use it in the treatment of everything just because it is now available is unworthy of men of science.

Penicillin itself is an acid which reacts chemically to form salts and esters. The sodium salt is the one at present available, although

calcium barium and ammonium salts have been used. The penicillin unit is an arbitrary measure based on a plate assay method developed by Dr. Florey, and is referred to as the Florey or Oxford unit. The pure salt is colorless but to obtain it in this form is at present impractical and apparently unnecessary. The yellowish color of the commercial product is due to harmless impurities and varies to some extent. This need cause no concern since freedom from toxicity and pyrogens, and a potency within 25 per cent of the stated level is guaranteed by rigid requirements of the Federal Drug Commission. Most products will actually assay higher than the potency indicated on the label. Assays in our own laboratory of the product of several manufacturers revealed only one instance of the converse of this.

The sodium salt is highly soluble and markedly hygroscopic, hence must be kept from contact with moisture until ready for use and at a temperature around 5°c. Under these conditions potency is not affected for at least three months. For so potent a therapeutic agent toxicity for man is practically nil. We have given 500,000 units in 100 cc. of saline intravenously in less than thirty minutes without significant reaction. Such dosage is still far below the toxic level for animals in addition to being unnecessary for the treatment of any condition so far known to be amenable to penicillin. Rarely urticaria may develop during the administration of therapeutic amounts. If this occurs, treatment should be discontinued since an occasional case of exfoliative dermatitis has been observed.

Rapid absorption and excretion is characteristic of the drug. Since it is destroyed by acid and organisms of the colon group it cannot be given by mouth or rectum. Within five minutes or less after intravenous administration it appears in the urine and after a short lag the rate of excretion parallels that of administration. Approximately 60 per cent of the amount administered, whether a single dose, multiple doses or continuous injection, is excreted by the kidneys. The fate of the remainder is not yet entirely known. It has been found in high concentrations in bile thus suggesting its use in certain biliary tract infections. It also appears in saliva but not in tears or pancreatic juice.[5] Serum levels rise rapidly after intravenous injection, somewhat more slowly after intramuscular and much slower after subcutaneous injection. For a given single dose serum concentration is higher after intravenous injection

than by any other method. On the other hand, while serum concentration does not reach the same height after intramuscular injection the level is maintained longer (thirty to forty-five minutes) and decreases more gradually. Following subcutaneous administration no penicillin appears in the blood for an hour and a half to two hours and the maximum concentration is much the lowest but, such as it is, remains the longest since excretion in the urine is prolonged. Since only traces are found in serum two and a half to three hours after a single intravenous or intramuscular injection, the method and frequency of administration become important in planning therapy. From the serum level standpoint, continuous intravenous therapy is most desirable, and for severe infections, gravely septic patients and in treating infections with organisms of low penicillin sensitivity this is the method of choice in our opinion. It has the obvious disadvantage of requiring fairly close supervision by an intelligent nurse and the prompt availability of resident physicians skilled in intravenous therapy.

During the past year we have had considerable experience with this method and have found that, properly anchored in a small vein of the hand, forearm, foot or ankle, using a No. 21 gauge needle, 1¼ inches long, the patient experiences little inconvenience, is able to move about, feed himself and even get out of bed. Most of our patients learned to regulate the rate of flow themselves and only one had special nurses. This coincides with the experience of Dr. W. E. Herrell of the Mayo Clinic. We have been able to maintain continuous flow at 10 to 12 drops a minute for fifteen days without removing the needle. By this means 100,000 to 400,000 units or more may be administered in a liter of solution per twenty-four hours thus avoiding excessive fluid intake if necessary. No decrease in potency of the solution was observed at the end of twenty-four hours. Pyrogen reactions have been encountered possibly due to continued use of the same tubing. No harm has resulted from these if the tubing is promptly changed, which can be done without removing the needle from the vein. Meticulous preparation of the intravenous set in accordance with the technic approved for blood banks would possibly eliminate these reactions. Within the past few weeks we have not had pyrogen reactions although using the same brands of penicillin, which tends to confirm the suspicion that there might have been an error in the technic of washing the rubber tubing. Venous irritation does occur frequently

but in our experience this subsides and the veins return to normal function in most instances. Actual thrombosis has been rare.

In summary it may be said that the administration of penicillin is, at present, a hospital procedure and that the continuous intravenous drip method is preferable whenever feasible since a more nearly constant serum level can be maintained. However, actual clinical results, notably in the treatment of gonorrhea, indicate that for many infections, fluctuations in the serum penicillin level are unimportant in obtaining a favorable result. Hence, the most generally practical and effective method of administration will probably be by intramuscular injection at three-hour intervals around the clock, started off by an intravenous injection of a dose two to three times that of the subsequent intramuscular dose. It is vitally important that the three-hour schedule be adhered to. Some good results have followed administration every four hours, but this should not be depended on in critical cases. We believe that repeated intravenous injections have manifest disadvantages and no advantage compared with the two methods outlined above.

The most frequently used concentration for single intravenous or intramuscular injections is 5,000 units per cc. of diluent which may be normal saline, 5 per cent glucose in saline, or distilled water. Recently, however, we have had patients complain of a burning sensation at the site of intramuscular injections when such concentration was used. This was not experienced when a concentration of 16,000 units per cc. was used.

We have had one occasion to give penicillin by continuous hypodermoclysis over a period of several days in concentrations of 200 units per cc. No discomfort other than that accompanying similar administration of normal saline was observed. However, in our opinion, this method should not be used except in the rare instance in which the patient "has no veins" and objects to repeated intramuscular injections.

In normal individuals penicillin does not pass into the subanachnoid space from the blood stream.[6] Therefore, to be effective in meningitis it must be given intrathecally as well as intramuscularly or intravenously. The usual intrathecal dose is 10,000 to 20,000 units. However, we have given 50,000 intrathecally without unfavorable reaction. There is no point in using penicillin routinely in meningococcic meningitis except in sulfonamide resistant cases. However, it is the drug of choice when a streptococcus or staphylococcus is the offending organism.

All hospitals at present designated as penicillin depots have copies of dosage tables as well as the indications and contraindications for the use of penicillin compiled by the National Research Council in accordance with clinical experience so far. To these you are referred for detailed discussion. Additional diseases in which penicillin is effective will no doubt be added to this list as our experience broadens.

Assuming that you have decided to use penicillin in a given case and since the currently available ampoules contain 100,000 units, a good rule of thumb is to administer 100,000 units in eight approximately equal doses every three hours around the clock. If clinical response is favorable, this dosage may be continued until temperature is normal then reduced to 50,000 units per twenty-four hours for the next five to seven days. If the response is not favorable, the twenty-four hour dose should be increased to 200,000 or even 400,000 units and continuous intravenous drip employed if possible. Failure to get a prompt favorable response to these doses indicates that either the causative organism is not penicillin sensitive or some localized abscess has not been drained, or the disease is due to mixed infection, or is bacterial endocarditis. Critical clinical judgment must then dictate what course to pursue. As an example of an immediately favorable result may be cited the first case of sulfonamide resistant pneumonia that we treated. Our supply was very meager and only 40,000 units were given the first twenty-four hours but this was sufficient to cause an immediate fall in temperature from 103°F. to normal with associated clinical improvement. A more recent patient illustrating the apparent need of larger dosage was admitted after a week of chills and fever following attempted abortion. Large doses of sulfonamide had been ineffective and her condition was critical; 100,000 units of penicillin by continuous intravenous drip were given the first twenty-four hours. The temperature dropped to normal but started up again before the twenty-four hours were up, so 200,000 units were given the second twenty-four hours. The temperature dropped to normal and remained so and she was discharged on the seventh day. Uterine culture showed hemolytic streptococci. Still another problem is illustrated by a child who developed signs of peritonitis following operation for a ruptured appendix. She was almost moribund when penicillin was started. Slow improvement resulted, the temperature became normal and it looked as if she was out of trouble, but the temperature again became septic in character. Penicillin was again given, the

temperature came down but the pulse and general condition remained unfavorable. Signs of abscess developed and drainage will have to be done before recovery can be expected. We have observed this tendency for the temperature to become normal under penicillin therapy even though other clinical signs are not equally favorable, and it demands a careful search for abscess formation or some other condition, such as thrombophlebitis or an associated organism not affected by penicillin.

The local use of penicillin has particular application in the surgery of trauma. Experience here is not so definite as in systemic infections. Some observers report favorable reports; others do not. Apparently the most favorable results have been obtained in acute situations, notably in empyema, suppurating joints, sinus tracts, osteomyelitis and infected wounds, in which the infecting organism is known to be sensitive. In treating empyema, joints or abscess cavities, aspiration or drainage must first be done, then the cavity partially filled with penicillin solution in a concentration of 250 to 500 units per cc. Repeated fillings daily, twice daily, or in rare instances oftener are necessary. Therapy should be controlled by daily bacteriological smears. Recently we administered penicillin intramuscularly in doses of 25,000 to 15,000 units every three hours to a patient who had multiple boils, one of which had been incised and drained just before injections were started. The abscess became sterile within twenty-four hours without local application of penicillin or other antibacterial agents. Boils in process of formation did not suppurate. The conjunctive will tolerate solutions of 250 to 500 units per cc. In very early acute osteomyelitis, before sequestrum formation, apparent cures without surgery have followed parenteral administration of penicillin. But once sequestrum or a draining sinus has formed, it is futile to use penicillin unless proper surgery is performed. The resulting wound offers a chance to use the drug incorporated in a paste made of lanette wax and vaseline.[7] In any gutter type of wound this has been found an effective means of application.

Other conditions of particular interest to surgeons of trauma in which penicillin has been used with good or favorable results are:

Surface Wounds and Burns. Sterilization of penicillin sensitive gram-positive organisms has been obtained by dusting with 1 per cent penicillin in sulfanilamide powder. If signs of sepsis develop, parenteral administration should be combined.

Deep Wounds. Fairly extensive experience in battle areas[7] indicates that several weeks' hospitalization may be saved and generally better end results obtained by closing such wounds immediately without extensive débridment. One or more rubber tubes are inserted directly into the wound or through stab incisions and allowed to project beyond the dressings. Tight suturing in layers is to be avoided and the sutures should not be placed too near the skin edges. Through the tubing 3 to 10 cc. of penicillin solution containing 250 units per cc. are injected twice daily for four days. Injection of too much solution is to be avoided. Sutures should not be removed too soon.

Cellulitis. Some of the early dramatic results were obtained in treating cellulitis with or without bacteremia since the common organisms are streptococci and staphylococci. Definite collections of pus should be evacuated. We have not personally observed cases of Ludwig's angina treated with penicillin but it would seem to be worth using in this infection.

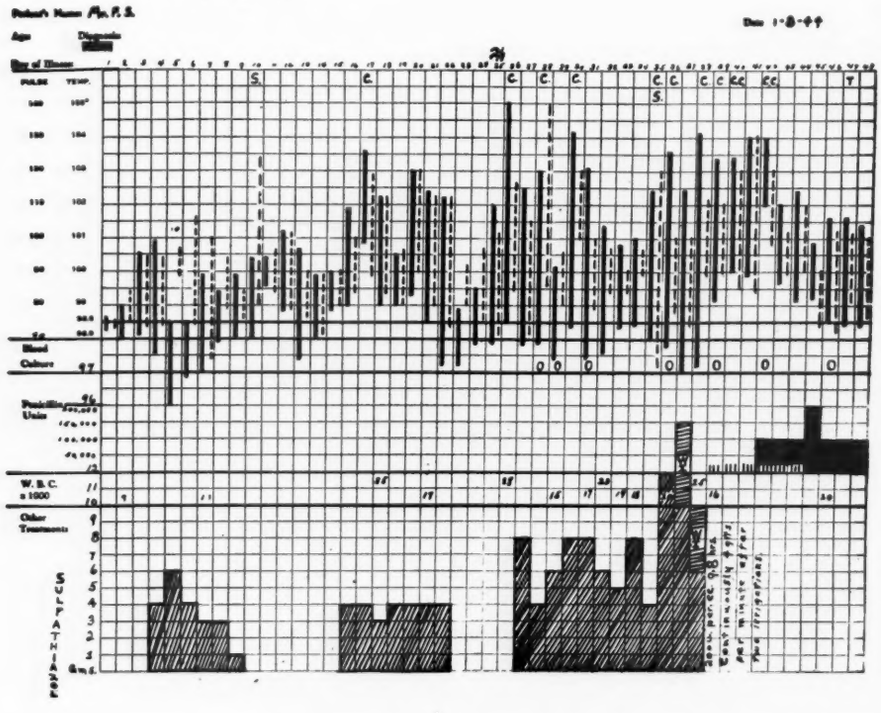
Infections of the Hand and Palmar and Tendon Sheaths. Local instillation of solutions by means of tubes plus parenteral administration has given encouraging results.

Cavernous Sinus Thrombosis and Infected Thrombophlebitis. Since the common infective organism in cavernous sinus thrombosis is staphylococcus, parenteral penicillin therapy is indicated. The same applies to infected thrombophlebitis anywhere if there is reason to believe the offending organism is penicillin sensitive. In both conditions we would employ heparin in sufficient dosage (about 150 mg. per day) to maintain a clotting time of forty-five to sixty minutes, or dicoumarin to maintain a prothrombin time about 250 per cent of normal. Coagulation time determination must be done twice daily and prothrombin time determinations once daily if either of these agents is used.

Gas Gangrene. While the organisms responsible for gas gangrene are penicillin sensitive, disappointing results have followed the use of penicillin alone. Large doses (up to 400,000 units per twenty-four hours) combined with anti-serum have given favorable results.

Compound Fractures. Experience from the battle areas has emphasized the importance of early closure of the wound and local treatment along the lines laid down under "deep wounds." In addition parenteral administration of 100,000 units daily should be instituted promptly. What can happen when these principles

are not carried out as well as other points in penicillin therapy may be illustrated by the detailed consideration of a patient whose chart is shown (Fig. 1):

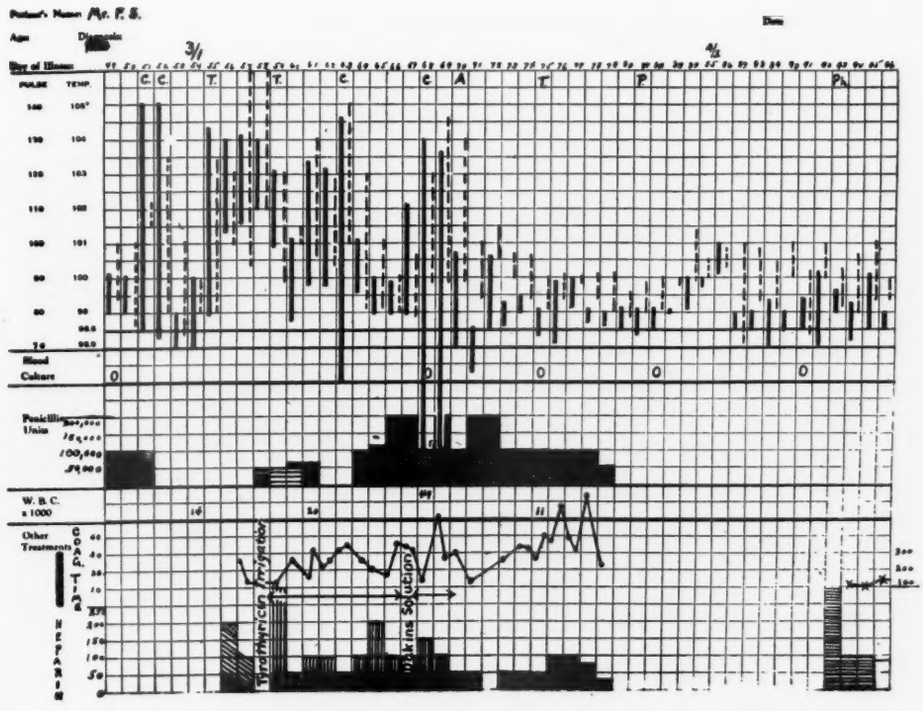


A

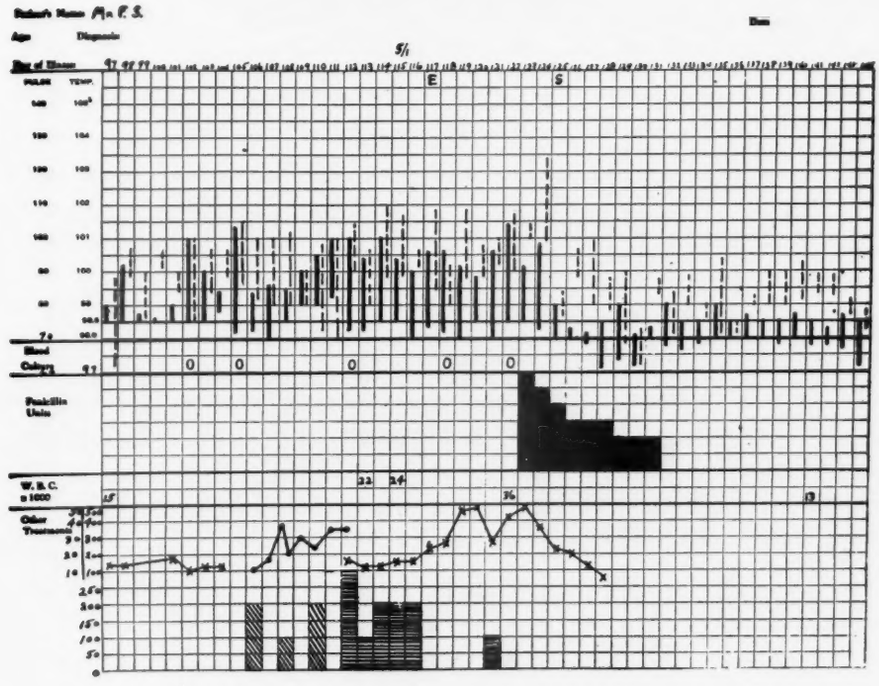
FIG. 1. Continuous, daily graph of patient with compound fracture referred to in text. A, solid line, daily temperature range; broken line, daily pulse range; diagonal hatching, sulfathiazole in Grams; W.I., wound irrigation with sulfathiazole; interrupted vertical lines, wound irrigation with penicillin; solid black squares, penicillin by continuous intravenous drip; S, incision and drainage; C, chill; T, blood transfusion. B, horizontal hatching in penicillin graph represents the only intramuscularad ministration. Diagonal hatching, intramuscular heparin in milligrams per twenty-four hours added to penicillin solution; horizontal hatching, dicumerol (lower graph) in milligrams per twenty-four hours; solid line with dots, coagulation time in minutes (Lee-White method); solid line with cross, prothrombin time in per cent of normal; A, amputation; P, pleurisy (possible pulmonary embolism); Ph, evidence of thrombophlebitis. C, pulmonary embolism (E); drainage of abscess of left thigh (S); other symbols same as in B.

CASE REPORT

The patient, a man of fifty-two, suffered a compound fracture of the left leg. When he entered the hospital on Dr. A. R. Metz' service about two weeks later local infection was already present. Evidence of systemic infection soon developed and an attempt to secure drainage was made. Cultures of the wound showed staphylococci. Blood cultures were sterile. Sulfathiazole was without effect. Again local incision for still better drainage did not improve the situation. Thrombophlebitis of the deep veins of



B



C

FIG. 1. For descriptive legend see opposite page.

the thigh extending apparently to the lower iliac branches developed. Local penicillin therapy, first by instillation of crude filtrate, then by continuous drip of solution of the sodium salt into the drainage tubes was tried without apparent effect. Penicillin, by continuous intravenous drip in doses of 100,000 to 200,000 units per day, plus heparin, was then instituted. A favorable temperature response raised the hope that the situation was under control. This was of short duration, however, and the patient grew steadily worse even while penicillin was being administered. His aversion to losing his leg delayed amputation until his circulation began to show signs of failure and his condition was desperate.

At this point a rapid guillotine operation was performed by Dr. Metz. Examination of the leg revealed one reason for failure of previous local and systemic treatment, namely, an abscess along and under the Achilles tendon not touched by previous drainage and impossible to locate unless the leg had been systematically ribboned. Improvement was immediate and dramatic. The tremendously swollen thigh and flank receded at the rate of half inch a day. Then the improvement stopped and signs of fresh sepsis developed, accompanied by tenderness in the thigh and swelling. Further thrombophlebitis was diagnosed and heparin* and dicoumarin* administered, followed shortly by penicillin by continuous intravenous drip. No improvement resulted and signs of localized abscess in the thigh developed. Incision carried down to the level of the deep saphenous vein evacuated about 1,500 cc. of pus. Improvement was again sudden and dramatic and this time apparently permanent as he has had a normal temperature for three weeks, is gaining weight rapidly and has the appearance of a well man.

This experience emphasizes the following points: (1) The necessity for early local and systemic penicillin therapy in compound fractures. We realized later that we depended too much on local drainage and sulfonamides in the early weeks after admission. (2) The ineffectiveness of systemic penicillin in the presence of undrained abscesses. (3) The poor results from local penicillin therapy of multilocular infections. (4) The false favorable temperature response to penicillin when all other signs remain unfavorable. (5) The value of penicillin in promoting a dramatically favorable postoperative course in a desperately ill patient when indicated surgery is performed. (6) The fact that penicillin cannot replace indicated surgery. (7) The value of anticoagulants in the therapy of thrombophlebitis.

* Most of the *beparin* and all of the dicoumarin (dicumerol) used in treating this patient was supplied through the courtesy of Abbott Laboratories. The intramuscular heparin used was obtained from Dr. Leo Loewe, Brooklyn, N. Y. and represents a special formula prepared for him by Hoffmann-LaRoche, Inc.

We believe that more extensive spread and embolism would likely have occurred without the use of these agents.

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DISCUSSION

Col. Robert H. Kennedy (Medical Corps): The ideas here expressed are the personal opinions of the discusser and it is to be considered that they represent in no way the opinions of other Army surgeons or the Medical Corps of the Army in general.

Penicillin treatment was commenced at the Percy Jones General Hospital in July, 1943. Up to the present time it has been used in over one hundred patients. We have found it apparently of great value in the small number of acute cases in which we have used it. Naturally, in a general hospital there are not many acute conditions in which it is to be advised, since these patients are more likely to appear in station hospitals. However, we have had occasion to treat one patient with erysipelas, one with acute sinusitis, one with acute mastoiditis, as well as several early wound infections. In all of these, in which a susceptible bacterium was found, it has seemed to us that excellent results were obtained. We have had no occasion to use it in acute blood stream infections.

For some time in our early experience it was used chiefly in the treatment of chronic osteomyelitis following gunshot wounds. Its use was continued for as long as seven and one-half weeks. None of us as particularly impressed with its value. It was possible to clear up streptococcus and staphylococcus in these wounds, but quite promptly proteus, coliform and

Bacillus pyocyaneus would appear. On stopping the drug, the streptococcus and staphylococcus were quite likely to re-appear. In these cases of chronic osteomyelitis, adequate complete surgery plays the most important rôle and penicillin can be considered only an adjuvant in the presence of foreign bodies or dead bone. We are unable even to state that in this condition penicillin is any more desirable than many other drugs that have been used in osteomyelitis.

It has been tried in several cases of empyema following gunshot wounds in which there were large cavities remaining, either with or without bronchial fistulas, both by local instillation and hypodermic administration and we have not been particularly impressed with its value.

In the past two months we have started using penicillin pre- and postoperatively in sequestrectomies and plastic revision of amputation stumps. Previously we had been using the sulfonamides for this purpose. There were reactions to the sulfonamides in a good many instances, which we believed to be due largely to the fact that most of these patients had had sulfonamides for one or more periods during their treatment previously. A poor appetite was frequent while sulfonamide was being administered, nausea fairly common and vomiting not rare. It is also too common to find red blood cells or gross blood in the urine. There were numerous instances in which the temperature rise was more than to be expected and in which it fell to normal when the sulfonamides were discontinued. For these reasons we changed to penicillin, with which in our entire experience there has been but little reaction. This consists almost entirely of an occasional case of urticaria and rarely a few red blood cells in the urine without symptoms. Nausea and vomiting have not occurred with penicillin in our experience. While using the sulfonamides it was rare to note any flare-up of cellulitis or other infection after sequestrectomy or revision of a stump. So far it has been just as rare to have this reaction following these operations with penicillin. Therefore, it is impossible to say that penicillin is any more effective for pre- and postoperative use in previously infected patients, but in our experience thus far, it has been at least as effective and without untoward symptoms. We usually give the drug for forty-eight to seventy-two hours preoperatively and continue postoperatively for five to seven days, discontinuing it then if general and local conditions do not seem to require its further use. It has been used pre- and postoperatively in two cases of lobectomy for bronchiectasis with rather marked infection. Each of these lobectomies healed well, but so have all the other lobectomies.

As time has gone on our dosage has in general become smaller. While we formerly used as much as 240,000 units a day, we now use in streptococcic cases 80,000 a day and in staphylococcic cases 120,000 to 160,000 a day. For intramuscular and intravenous use we make up the drug in 10,000

units per cc., and for local use in 250 to 1000 units per cc., usually 250. We have found that in an Army hospital intramuscular use is most satisfactory for continued administration, although in an acute case it is given both intramuscularly and intravenously for the first twenty-four to forty-eight hours in order to get in a large dose. There is no use in its administration unless it is to be given at least every three hours, day and night. This, of course, makes it administration difficult in anything but hospital practice. A few patients complain of burning sensation following intramuscular injection.

Quite recently we have had two patients whose clinical course suggested early gas bacillus infection. It is fair to state that gas bacilli were not proved in either case, although in one instance there were two considerable areas of necrotic muscle found on opening up the street wound which had been primarily sutured elsewhere. In each instance there was prompt thorough surgery accompanied by local and general use of penicillin and both cases responded promptly. We believe that we can express no opinion about the value of penicillin in gas infection.

It is unfortunate that the public has been brought to believe that this is such a miracle drug. It is our belief that it is a most valued addition to our armamentarium, but that proper complete surgery is more important than any drug.

WALLACE E. HERRELL (Rochester, Minn.): Penicillin therapy, I believe, may be recorded as one of the great advances in medicine, and for that reason the enthusiasm with which it has been received is unparalleled. This enthusiasm must, of course, in time be tempered as more and more is learned about the uses as well as the limitations of penicillin.

As I looked at the bottles which Dr. Priest showed a few moments ago in which penicillin was grown, I could not help but think of the transition which has occurred since Professor Florey visited at the Mayo Clinic in 1941, at which time we had these flat bottles all over the laboratory. As you may recall, it required 100 liters of the brew at that time to obtain enough penicillin to treat one patient for one day. What has happened since then is, of course, a great accomplishment and a great tribute to the scientific and industrial organizations of this country.

With regard to the local use of penicillin, I might remind you that the broth filtrate containing penicillin has proved satisfactory particularly when one does not have available the more purified penicillin. The broth filtrate is an entirely safe agent and can be obtained by simply filtering off the mold from the broth in which it is grown. This broth as well as the sodium or the calcium salt has been used with good results in the local treatment of bacterial infections. The sodium salt in the bulk is somewhat irritating. On the other hand, the calcium salt has not proved to be irrita-

tive. The calcium salt is also more stable as evidenced by the fact that my colleagues and I have kept calcium salt in the dry state for as long as six months at room temperature without finding any loss of potency. This, we believe, is of tremendous value particularly in connection with its use in theaters of war where refrigeration is not always available.

I was much interested and gratified to learn that Dr. Priest and his associates have found the continuous intravenous drip method of administering penicillin satisfactory. We have always believed that it was a satisfactory method if one is equipped to handle it. This much is certain, it is the only safe way by which a constant level of penicillin can be maintained in the blood. The burning sensation and local irritation associated with repeated intramuscular injections at times are somewhat troublesome. It has been apparent recently, however, that the degree of pigmentation of penicillin itself may affect this reaction somewhat. While the local or systemic reactions vary with different batches of penicillin, there is some evidence that the more deeply pigmented the penicillin is, as a rule, the more likely one is to encounter these side effects.

A word about the use of penicillin in the treatment of suppurative diseases of the joints and osteomyelitis which are, of course, of primary interest to this group. I concur completely in the opinion that penicillin is effective in the treatment of acute osteomyelitis. I might remind you, however, that the so-called masking effect which has been noted in the past in connection with sulfonamide therapy may occur with penicillin therapy in the treatment of acute hematogenous osteomyelitis. In one or two patients who were under treatment with penicillin for acute osteomyelitis, we have been badly fooled concerning the success of the treatment by the development of some quiet lesion which could be identified only by roentgenologic examination. In the treatment of chronic osteomyelitis penicillin alone is not the answer. Unless one is prepared to eradicate the focus and then combine penicillin therapy with other accepted forms of treatment, the results are not going to be satisfactory, at least this has been our experience at the clinic. I also might mention that the results in the treatment of osteomyelitis of the flat bones are in general better than the results obtained in the treatment of osteomyelitis of the long bones. We also have obtained satisfactory results in the treatment of subacute or spreading osteomyelitis of the flat bone owing to anaerobic and partially anaerobic streptococci.

I believe one of the discussants has already dealt with the question of phlebitis which occasionally may occur following the intravenous administration of penicillin and also the question of pyrogenic reactions. However, these pyrogenic reactions are not troublesome at present since practically all the penicillin available is pyrogen free. The only other toxic reaction of any significance which deserves mention at present is the urticaria and

dermatitis which may be encountered in no more than 2 or 3 per cent of patients. This skin reaction is bound to occur in certain individuals who are sensitive to molds and to mold products. If a severe dermatitis occurs during the course of penicillin therapy, one caution should be exercised: if one continues to force penicillin in the face of such a lesion, the possibility that a more extensive and probably exfoliative dermatitis may develop must be kept in mind.

WALTER S. PRIEST (closing): I was hoping Colonel Kennedy would mention the primary closure of wounds which has been done at some of the battle fronts. Having had no personal experience, I felt inadequate to discuss it. Reports have indicated good results. Extensive débridement is not done. Wounds are merely cleaned, dusted with penicillin and sutured. Sometimes a small stab wound is made and a rubber tube drain inserted through which penicillin is subsequently instilled. It might be a point worth investigating by those of you who see wounds of this type.

I am glad both Colonel Kennedy and Dr. Herrell deplored the tendency at present for penicillin to be used for anything and everything. We are seeing it used that way around the hospital, and it should not be done.

I observed one case of spreading osteomyelitis of the jaw, in which penicillin was ineffective, but I think in general the experience would coincide with that of Dr. Herrell.

DEQUERVAIN'S DISEASE

STENOSING TENDOVAGINITIS AT THE RADIAL STYLOID

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BRIDGEPORT, CONNECTICUT

SOME years ago Dr. George Hawley[1] called my attention to a painful condition of the wrist which has become known as DeQuervain's disease. It is a thickening of the tendon synovial sheath and the overlying annular ligament at the groove in the outer border of the lower end of the radius that transmits the tendons of the abductor longus pollicis and the extensor brevis pollicis muscles. This groove runs downward and forward and is covered by the annular ligament which forms a separate compartment for the two tendons. (Fig. 1.) The tendons are surrounded by a sheath that extends an inch above and an inch below the annular ligament. This sheath is filled with synovial fluid to facilitate the pulley-like action of the tendons. The tendon of the abductor pollicis is inserted into the base of the metacarpal bone of the thumb and the tendon of the extensor brevis pollicis into the first phalange. The cause of the thickening of the sheath and ligament is primarily mechanical irritation. Eschle[2] thought that over exertion caused increased friction, that the sheath became edematous and later thickened from fibrous tissue formation. In early cases on opening the sheath a small amount of synovial fluid is found; in advanced cases we have found it dry. The tendons rarely show any change in appearance though in some cases a constriction has been noticed from pressure. Similar changes have been observed in other tendons where they are angulated within a tendon sheath such as those causing "snapping thumb" and trigger finger.

While DeQuervain[3] has been credited with first describing this condition in 1895, there appears in Gray's Anatomy, 13th edition published in 1893, the following note: "The tendons of the extensor muscles of the thumb are liable to become strained and the sheath inflamed, after excessive exercise, producing a sausage-shaped swelling along the course of the tendon, and giving rise to a crackling sensation to the finger. As it was often caused by such movements as wringing clothes, it was known as "Washerwoman's Sprain." I believe this was the same condition that we are discussing.

As it was about the turn of the century when the mechanical wringer was introduced, one might surmise that its use led to a lowered incidence of the disease, only to have a renewed frequency

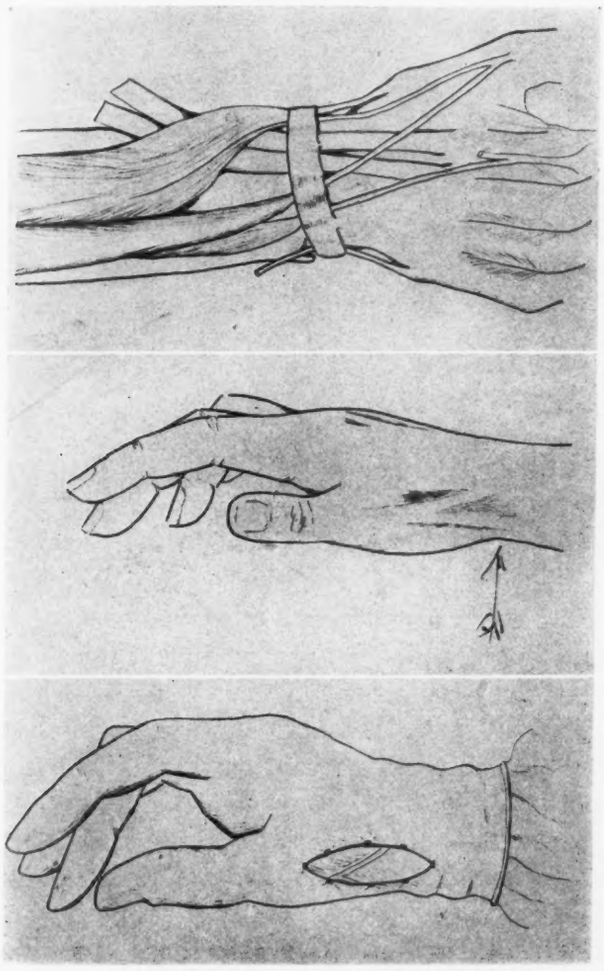

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 1. Shows tendons of short extensors of thumb passing under annular ligament at radial styloid.
FIG. 2. Snuff box, shows short extensors of thumb forming lower border.
FIG. 3. Shows method of protecting field of operation. Opening in rubber glove is over radial styloid.

as women became actively engaged in factory work which required excessive use of the thumbs.

Dr. Morrison and Dr. Cotton[4] have pointed out that this condition has received but scant attention in text books or surgical literature and this is true. I believe that the disease is not generally

recognized and that quite a number of cases are under treatment for sprain, arthritis, neuritis, osteitis, periostitis or tenosynovitis. From conversation with surgical friends I find that very few of

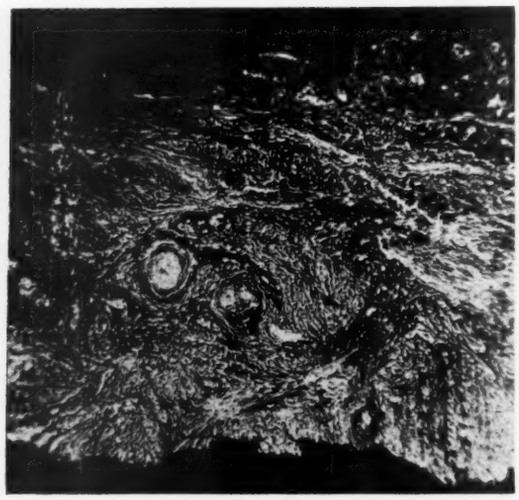

FIG. 4. Microphotograph of section removed at operation.

them are familiar with the condition, though they all were sure they had seen such cases but had failed to recognize them. The condition is not uncommon, for at one time in the Summer of 1942 we had five patients under treatment. When one has it in mind the diagnosis is easy, and I know of no condition in which the results of treatment are more satisfactory both to the patient and the surgeon.

The etiological factor is undoubtedly trauma, and this is generally of a chronic nature. In most of our cases the patients were engaged in occupations that required pressure by the thumb while it was in a partially abducted position, such as work on a grinding or buffing machine. In one of our cases the patient, a woman, was employed putting tight fitting rubber rings over a piece of pipe. To do this she would press firmly on the ring with both thumbs. One day in order to complete a rush order she performed this act five hundred times. That night she had severe pain in both thumbs. We saw her a month later when her symptoms were still severe in spite of the fact that she had been receiving local treatment since the injury. Another patient pressed clothes with a heavy iron. Dr. Frederick Cotton[4] reported a case occurring as a result of fly casting with a light rod.

Since a previous report in 1935 I have seen several cases in which the patients stated that their symptoms followed a blow on the wrist or a fall on the hand. In some cases I think the blow or fall was coincidental or aggravated a pre-existing condition, because the work of these patients was such as to favor tenosynovitis. I am not convinced that this condition can result from a single trauma, as the condition definitely suggests a chronic disease.

There is a great preponderance of the disease in females. Finkelstein[5] reported only four male patients in twenty-four cases; and Schneider[6] fourteen males in 135 cases that he collected. In a series of thirty-two cases we had eight males and twenty-four females.

The symptoms and signs of DeQuervain's disease are quite definite and the similarity in all cases is very striking. As a rule the onset is gradual. The patient will complain of pain in the wrist of several weeks' duration and when questioned will locate the pain over the radial styloid. They also refer to pain running up the arm and downward into the thumb. Pain is aggravated on abduction of the thumb, or ulnar adduction of the hand. This can be demonstrated by flexing the thumb in the palm of the hand, and with the fingers closed over it making sharp ulnar adduction. The pain gradually increases with use of the thumb. Later weakness of the hand develops and patients complain that they drop even small objects. Considerable disability usually results. Objectively, there may be slight swelling over the affected part. There is marked tenderness over the styloid process. (Fig. 2.) Abduction of the thumb is restricted and forced adduction is painful. Crepitation can be felt only rarely.

There have been some cases of recovery reported under non-operative treatment, but the time required to get relief was from four months to two years. I have one patient who refused an operation but her work had to be changed, and even two years after this was done she showed signs of the disease. Another patient who had been treated with plaster immobilization for six months without benefit had quick relief after operation. A few years later she developed the condition in the other wrist and requested immediate operation. I should think the recurrence rate after conservative treatment would be great and immobilization with a plaster cast on the hand is a discomfort in itself.

The operative treatment is so simple, giving early relief of pain and a period of disability so short, that it should be the treatment

of choice in all cases. This is well illustrated by two patients I examined recently. Both worked at the same job. Mrs. G., aged fifty-one developed bilateral DeQuervain's disease in October, 1940. She refused operative treatment and stopped her work which had required a twisting motion of thumb and wrist. She had some relief of pain from adhesive strapping of the thumb. She remained out of work for six weeks, and when she returned her job had to be changed. For over two years she showed signs of the disease. When seen last month all symptoms and signs were gone, but she would not go back to her previous occupation. Mrs. H., aged fifty-three had symptoms for about six weeks. She had constant pain and complained, "I can't hold anything." She was operated upon January 22, 1944, under local anesthesia, returned to her usual work on February 1st, and when seen last month said she had had no discomfort since doing so. Her period of disability was exactly one week.

The operation is conveniently performed under local anesthesia. After proper preparation of the hand and forearm, a sterile rubber glove is put on the hand and a small opening made through it over the operative site. (Fig. 3.) We have found this a very satisfactory protection in operations on the hand and fingers. A tourniquet is applied and a short incision made over the radial styloid. Care should be taken to avoid a small branch of the radial nerve. The carpal ligament and tendon sheath are exposed. In fully developed cases they have somewhat the appearance of a miniature infantile pyloric hypertrophy. The thickened tissue over the styloid groove is incised; it generally gapes, exposing the tendons. Nothing further need be done to the sheath. The skin incision is then closed in two layers, and a firm bandage applied. No splinting is necessary, and the thumb is not immobilized. Free motion of the thumb is permitted in two days' time, and full use is generally possible at the end of two weeks. We have had no case in which relief was not obtained.

Finkelstein recorded his microscopical findings as follows: "In mild cases the synovial membrane is thickened except at the point of constriction where it is thin or absent. The loose connective tissue layer is considerably thickened and vascularized. The ligamentous layer is slightly thickened and not vascularized. Only rarely is there a line of demarkation between the loose connective tissue layer and the ligamentous layer. In severe cases the synovial

layer is completely destroyed; the loose connective tissue layer is compressed and thinned out; while the ligamentous layer is markedly thickened and undergoes hyaline and cartilaginous transformation. There is also marked thickening of the walls of blood vessels, and cellular infiltration of the tissues, numerous lymphocytes being present. Between these two types are many gradations." All of our sections have shown similar changes. (Fig. 4.)

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DISCUSSION

Gordon M. Morrison (Boston, Mass.): Dr. Patterson has left little to be said. He has done a good job on the subject. I like a dry field in order to identify the sensory branch of the radial nerve to the thumb so that it may be retracted and not injured.

As Dr. Patterson has said, removing the cartilage-like housing on the tendons is simple, permitting the tendons to move freely right away. Then suture the skin, start motion within forty-eight hours, and the results are excellent.

RECONDITIONING FOR THE WAR WOUNDED

THE UNITED STATES ARMY SERVICE FORCES' PROGRAM

COLONEL AUGUSTUS THORNDIKE
MEDICAL CORPS, ARMY OF THE UNITED STATES

UNTIL the infamous attack on Pearl Harbor it had been the policy of the Medical Department routinely to grant convalescent furloughs to soldiers hospitalized for any great length of time. However, upon the outbreak of hostilities it became increasingly discernible that the convalescent furlough was ineffective and impractical as a means of promoting rapid convalescence of disabled soldiers during wartime. Far too many patients returning from convalescent furloughs were found to be in inferior condition to that with which they departed. Once at home the soldier, and especially the experienced combat soldier, was usually caught up in a whirl of strength-depleting social activities provided by well intentioned friends and relatives anxious to entertain or amuse the soldier on furlough.

The physical demands made on the soldier by participation in the intensified training program, or engaging in active combat, made it imperative that the convalescing patient not be returned to a duty status until he had completely regained his lost stamina. The urgency of the military situation, on the other hand, necessitated a reduction in the time absent from duty, because of illness, consistent with the welfare of the soldier. The Reconditioning Program was developed as a solution to this reduction in the non-effective rate of field units.

This program provides for the soldier recuperating from wounds, illness or injury, a regimen of activities designed to hasten his return to duty in that high state of physical and mental health recognized as an indispensable precursor to effective participation in any intensive military training. It is also being used with gratifying results as a proving ground, where soldier patients disqualified for full military duty are evaluated under working conditions for the purpose of determining assignments commensurate with the disability.

BED PATIENT

The reconditioning regimen for the bed patient, who has entered the convalescent stage, consists of a program comprised of three

integral parts: First, physical reconditioning composed of short daily periods of light bed exercises of various types designed to allay muscular atony and atrophy in those parts of the body not diseased or injured; second, educational reconditioning composed of an organized program of lectures, group discussions on topics of general interest, study of approved credit courses in the United States Armed Forces Institute, reading or observing of current items in papers, magazines or radio or motion pictures in the ward, intended to promote that natural instinct of ever seeking after the truth and the desire to learn more of the reasons why we fight; and third, occupational therapy consisting of light purposeful tasks, creative art or handicraft, such as making medicine swabs, folding dressings, fabricating camouflage nets, helmet nets, leather working and wood carving. Objectively directed in bed occupations have been found of considerable assistance in the restoration of function to injured or diseased parts of the body. Perhaps in the recent past so-called "bed rest" has provided too many periods of physical and mental idleness. This program is aimed to avert such idleness.

AMBULATORY PATIENT

The physical reconditioning prescribed for the ambulatory ward patient is more strenuous and includes calisthenics, remedial exercises, light gymnastics and mild games such as croquet, quoits and horseshoes. These exercises have as their purpose the gradual restoration of normal physical vigor, while the patient still requires ward care.

The educational program for the ambulatory ward patient is designed to develop within the patient the desire for a speedy return to health, while increasing his general knowledge by providing lectures and conferences on various educational subjects. Through encouraging the patient to study United States Armed Forces Institute correspondence courses with a view to completing credits for his high school diploma or college degree, a profitable experience is offered. At this time 115,000 soldiers are enrolled in these courses (9,000 represent fourth year high school students). A large percentage of this student body is in overseas stations. Time in hospital has been found to be an appropriate time to start such an activity.

Ambulatory patients engage in more strenuous types of occupational therapy, such as cabinet making, weaving, fly tying, printing, pottery making, etc., all such activities carried on in a

shop. They are required to make their own beds, assist less agile patients in self-care, and are assigned for short periods daily to various departments of the hospital to assist Medical Department personnel.

ADVANCED RECONDITIONING SECTION

When ward or clinic treatment is no longer required, soldiers, whose illness or hospitalization has been so brief as not to permit of any appreciable loss in condition, are returned directly to duty, while all others who may be expected to return to duty, are admitted to the Advanced Reconditioning Section for further physical training. The greater part of this training is devoted to physical reconditioning activities co-ordinated with a few hours per day of intensive military training.

Since the restoration of a patient to full health progresses much more rapidly when the convalescent period takes place outside of the hospital, Advanced Reconditioning Sections simulate the average training company as closely as possible. To this end patients are housed in barracks detached from the hospital, clothed in regular duty uniforms, granted all of the privileges normally afforded the soldier on a full duty status, subjected to the same rules of discipline, and are referred to as "trainees."

The physical training program provided for the trainees includes gymnastics, combatives, obstacle course running, games, calisthenics, swimming and marches up to fifteen miles.

Educational reconditioning for the trainee is limited to two hours per day of instruction in subjects which actually constitute a refresher course in basic military training. Emphasis is placed on map reading, scouting and patrolling, weapons and their uses, first aid, and field sanitation. At certain station hospitals where the troops hospitalized are predominantly of one branch, such as at a Signal Corps Replacement Training Center, the patient trainee is provided instruction similar to that which he would receive in his company and thereby loses no training time while hospitalized.

The occupational therapy prescribed for the trainee consists of useful activities such as painting, plumbing, gardening, carpentry and the like—work therapy for the benefit of the hospital.

Throughout the entire program physical reconditioning activities are prescribed by medical officers and executed under the guidance of trained instructors. The intensity and duration of exercises

are increased in direct ratio with the progress made by the patient, but under the guidance of the medical officer.

Patients unfit for full military service are frequently assigned to the Advanced Reconditioning Section where they are studied under working conditions with a view to determining a duty to which they might be reassigned, the performance of which would involve activity commensurate with their remaining capacities. If this disability precludes further military service, he is required to attend a brief course of instruction in the responsibilities which one would be expected to assume as a civilian. Manpower is being salvaged for both the Army and War Industry by this procedure.

In an appraisal of the progress made thus far, manifest results stand as incontrovertible evidence of considerable success attained. The magnitude of the task which lies ahead constitutes an ever present warning that, if one is to succeed, there can be no relaxation of effort.

We are now engaged in the actual procurement of qualified personnel, the assignment of officers and enlisted men who are at present performing other duties within the Army. Four courses have been established at two schools for the purpose of providing technical instruction for both officers and enlisted men to qualify them as physical and educational reconditioning instructors. The dearth of scientific publications pertaining to the reconditioning field has forced us to prepare a complete manual describing approved reconditioning practices and technics. A motion picture is also being produced for the purpose of educating duty personnel in the technical aspects of reconditioning. The reconditioning program is now operating in all Army Service Force Hospitals in the continental United States, as well as in each overseas theater.

The establishment of a reconditioning service in Army Service Force hospitals has been authorized with a Chief of Service at the same organizational level as the Medical and Surgical Services. The Chief of this service is responsible to the Commanding Officer and controls all phases of this program with a very close liaison with the professional staff of the Medical and Surgical Services. No patient can enter the program without the approval of the ward officer or chief of section. Approximately 70 per cent of the patient population of each hospital is participating daily in this program.

It is an uncompromising resolve, however, that every soldier returned to duty from an Army Service Forces hospital shall have

restored to him the strength, endurance, agility and ruggedness prerequisite to effective training or combat. The practical significance of battle casualties returning to the front lines in their unit with such an attitude of mind, can hardly be exaggerated.

It is a confident hope that as the scroll of destiny unfurls, in the post-war era we shall find that from the pioneering of the Medical Department of the United States Army in this relatively unexplored field of reconditioning, there shall have emanated a basis for the establishment of scientifically sound procedures for the accomplishment and acceleration of convalescence. These three phases of the balanced program, physical, educational and occupational reconditioning, are essential to produce results. Bed patients, ambulatory ward patients and trainees all must experience a balanced program—a progressive program in all phases and tasks.

Results at this time have proved that the hospital stay and the readmission rate have been reduced, and that the soldier patient is returned to duty or to civilian life better conditioned, better educated, informed and oriented—a better soldier or veteran.

DISCUSSION

Col. Don G. Hilldrup (Medical Corps): Colonel Thorndike has discussed the purpose and outlined the scope of the reconditioning program as it is being carried out in Army Service Forces hospitals. The value of the program is largely dependent upon the active and enthusiastic participation of every member of the hospital staff. It is sometimes difficult to sell new ideas to people who have for years followed a certain line of thinking. Therefore, to make the program successful, all personnel having to do with it must be well indoctrinated in its principle and sold on the idea.

The Army is at present confronted with two very vital problems concerning hospitalization: First to keep specialized beds available, and second to prevent physical and mental deterioration among patients. In the early days of the war and during peace times, personnel often objected to being sent to Army General Hospitals because the stay was usually prolonged and it was difficult to obtain a discharge to duty. With enlargement of the Army and the scarcity of medical officers to staff these hospitals, the necessity for decreasing hospital days became imperative. Further, it was found that the longer a patient remained in the hospital the less was his desire to return to active military duty. In other words, morale decreased as the days in the hospital increased. The old adage that "idleness was the Devil's workshop" was never better illustrated. Reconditioning, therefore, has a three-fold purpose: First, to expedite convalescence and the return of full physical powers; second, to occupy the idle hours of the

patient both from a mental and physical standpoint; third, to improve morale, morale being defined as that intangible mental attitude which causes an individual to be satisfied with his position and eager to do his job quickly and thoroughly.

It is too early to evaluate the accomplishments of this program finally. It is clearly apparent, however, that desirable objectives are being attained and that convalescence in the average hospital case is reduced approximately 30 per cent. Soldiers with debilitating diseases and injuries are being rehabilitated in a shorter time than formerly and returned to their organizations in physical condition which permits them to slip into service routine without undue fatigue or relapse. They return with more enthusiasm than formerly, and the mental attitude of the convalescent is improved. In the Sixth Service Command there are 4 General Hospitals having in excess of 6,000 beds, as well as several large Station Hospitals in excess of 1,000 beds each. The reconditioning program is being carried out in all of these. We are now establishing a Convalescent Camp in Michigan, to which all Class I and II patients will be sent for intensive reconditioning. By this program the percentage of ambulant patients in our hospitals, which now averages 70 per cent of all patients, will be reduced to approximately 30 per cent, thus increasing our available beds by approximately 3,000. When this plan is applied to all the larger Army hospitals in continental United States, it will increase the bed capacity in excess of 100,000 beds by the elimination of ambulant convalescents. It is expected that these beds will shortly be required for casualties resulting from the present military operation in Europe.

An Army medical policy which is fixed and unalterable is to give the hospitalized soldier the best medical attention that the country affords. By means of frequent and thorough inspection by competent professional consultants it is possible for the Surgeon of a given command to maintain in responsible positions only those medical officers whose capabilities and work measure up to required standards. Thus with professional care of the highest order, supervised reconditioning will not only accomplish its end as planned but will decrease the routine load of the hospital medical officer. It will effect an economy of professional talent which at the present time is the greatest problem of the Medical Department.

Lt. Col. Francis M. McKeever (Medical Corps): Before discussing the Army's program for rehabilitation of the amputee, I would like to sketch briefly the situation which the Army today is faced with in caring for patients who have suffered amputations. This problem differs in many respects from that of civilian life, not only as to magnitude but as to character. Needless to say, the number of amputees is greatly increased. In addition to this the patients are of a different age group. They are men for the most part in their twenties or early thirties who in the future must

earn a living. They are, in large percentage, men who followed arduous occupations requiring strength and agility prior to their Army service.

In civilian life most amputations are done in elderly people because of

FIG. 1. Type of artificial leg used.

vascular disease or because of malignant tumors. Only a relatively few are brought about by trauma. Consequently, closed amputations are performed and the operation is completed at one sitting. Six to eight weeks after operation the patient is ready for a prosthesis. On the other hand, the amputations resulting from combat are all the result of trauma and are all infected or potentially infected. The initial operation is often done under unfavorable circumstances. The patients must be sent through a chain of evacuation away from the site of activity. They not only leave the care of the surgeon, who did the operation, but pass through the hands of many different surgeons during the crucial period of postoperative care when bacterial invasion may be lethal.

Because of these facts, closed amputations are not done on battle casualties requiring the removal of an extremity. All amputations done at the front are open or guillotine amputations and it is understood that a

FIG. 2. Patient walking with crutches.

secondary operation consisting of a reamputation or a plastic closure will be necessary at a later date to produce the final stump. This policy is absolutely necessary in war to prevent useless loss of life and useless sacrifice of bone length from sepsis.

To afford proper care and proper rehabilitation to the amputee certain Army General Hospitals in the Zone of the Interior have been designated as Amputation Centers. All patients who have suffered amputations in the Army are sent to the Amputation Center nearest their home locality. They cannot go to the hospital nearest their home but must go to the hospital organized as an Amputation Center, which is nearest their home.

The Amputation Center brings together the following features: (1) A surgical staff experienced in amputations; (2) an artificial limb shop; (3) physical therapy; and (4) occupational therapy. The following policy has been adopted relative to the discharge of a patient from an Amputation Center: First, all patients must be fitted with a prosthesis. Second, the patient with a lower leg amputation or an end bearing thigh amputation must be able to walk well on level ground without a cane. A patient with a mid-thigh or high thigh amputation must be able to walk well on level

ground with no more aid than a cane. Few patients with the exception of those having the very short thigh stumps use a cane. Third, an arm amputee must be supplied with both an artificial hand and the utility hook and

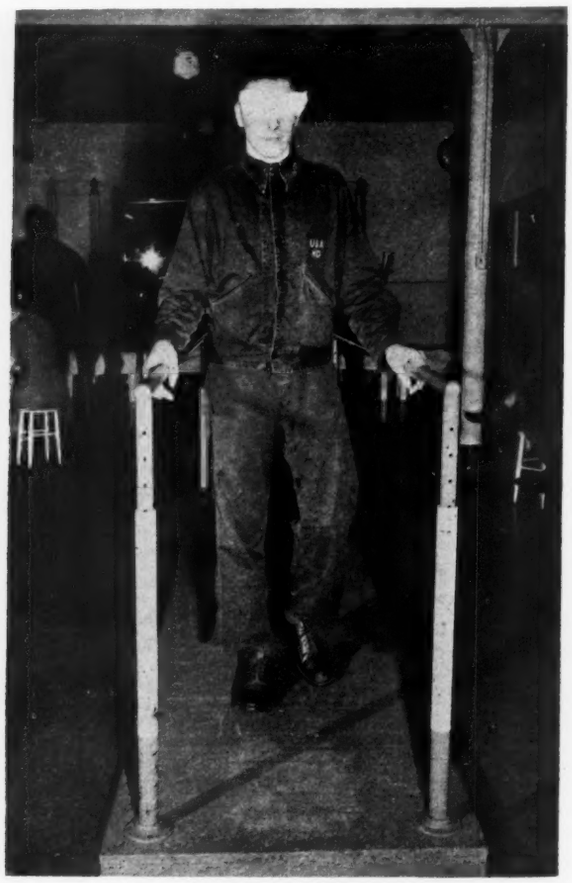

FIG. 3. Patient walking in ramp.

must be able to write, to eat, to dress himself, and to keep himself clean without help. When these objectives have been accomplished, the patient may be returned to civilian life or if he desires, an attempt will be made to find a place for him in the Army.

In order to accomplish the above end the surgeon must first of all do what surgery is necessary to produce a good stump. As practically 100 per cent of the patients have previously had a guillotine amputation at the lowest possible level, and since many of the extremities have suffered multiple wounds, the surgeon may be greatly compromised from a cosmetic viewpoint. It may be impossible to place the scar at the optimum point or iron out all furrows on the stump without sacrificing uselessly good bone length. Either a reamputation at the site of election or a plastic

closure is done. For example, a leg which had previously had an open amputation through the knee joint would be reamputated at the supracondylar level; a very short thigh stump would have a plastic closure with

FIG. 4. Patient walking without any support.

as little sacrifice of bone as might be necessary to permit of a good closure of the skin.

As soon after surgical closure as the stump will permit, bandaging with elastic bandages is started to promote shrinkage of the tissues. This treatment is usually tolerated about the tenth day after operation. At about twenty-one days it is possible to further hasten the shrinkage of the stump and increase the circulation of the tissues by massage started lightly and increased in intensity.

At this time it is usually possible to institute exercises to develop the muscles necessary for a good gait and to stretch out any contractures which may have developed. It is not uncommon for the thigh amputee to have a hip flexion contracture, for the below knee amputee to have a hamstring contracture, and for the arm amputee to have a pectoral contracture. For good walking the thigh amputee needs strong hip extensors and strong hip adductors, otherwise the gait will be lurching. The below knee amputee needs a good quadriceps, otherwise, he cannot control the knee and the

prosthesis may let him down. It is obvious that no arm prosthesis can be worked effectively with a pectoral contracture and that a strong deltoid muscle must be developed. The bandaging, massage, and exercise all hasten the shrinkage of the stump.

When the initial edema and swelling incident to the operation have subsided, and when the incision is well healed, the patient is fitted with a prosthesis. This can usually be effected six to ten weeks after the final operative procedure. The prosthesis with which the patient is fitted is not a peg leg or pylon, but is an artificial extremity containing joints and is similar in basic construction to all artificial extremities. It is made, however, of a fiber material which can be adjusted frequently in the leg shop to compensate for the rapid shrinkage which follows active use of an extremity. This leg is fitted individually to each patient by taking a plaster mold of the stump and making an individual socket for each amputee.

After being fitted with the leg the patient is then taught to walk. He is taught first with crutches as the stump in the early stages may be sensitive. He is next given individual walking instruction and exercise in a ramp, being drilled in the proper muscles to use, the proper steps to take, and is shown the common mistakes to avoid, such as looking at his feet, walking with a wide base, etc. When a good gait has been mastered and the patient handles himself well without any support, he is graduated to a class, which in addition to walking drill, also includes calisthenics aimed at co-ordination. During all this time active resistive exercises to develop the important muscle groups are carried out on each patient each day.

The upper extremity amputee is sent to occupational therapy in addition to physical therapy. The occupational therapist trains the patient in activities requiring the use of both hands. Each arm amputee is taught the use of the hook and of the artificial hand for eating, for lifting, for dressing, and other more advanced and complicated activities. If the amputee has been a right-handed individual and lost his right arm, he is taught writing with the hook and artificial hand. Most patients who have lost their right arm, however, have already acquired considerable skill in writing with the left hand by the time they are ready for this program. In the weeks which elapse during transport of a patient from the Antipodes or Mediterranean, the vast majority have acquired the ability to write very legibly.

In addition to the above outlined procedures there is also a dancing class held daily in which ballroom dancing is taught. This is optional. It is much enjoyed by the men and does a great deal toward restoring self assurance. There is also an automobile available, and an instructor in driving, himself an amputee, who teaches the men to operate a motor vehicle with their prosthesis.

For any individual whose mental adjustment to the loss of his extremity is inadequate, the attention of a trained psychiatrist is available. In our

experiences his services have been but rarely necessary. The overwhelming majority of these men meet their problem with a smile and when they see the progress of those about them, buckle down to hard work. It can be said without reservation that the morale of the amputee is the highest of any group of hospital patients.

Concomitantly with the above program the patient has the opportunity for orientation courses, has access to a library, which through affiliations will obtain for him practically any type of text or literature that he may desire. The amputee is also given the opportunity of taking additional work in occupational therapy where leather work, crafts, printing, power tools, draughting outfits, painting equipment, sign making apparatus, and various other facilities are available.

When the patient and prosthesis are well adjusted to each other and the individual has no discomfort from its use, he is given a lengthy furlough if desired. In this way each individual gets an opportunity to meet his previous environment. On return from this furlough the stump is usually further shrunken and appropriate adjustments are made in the bucket of the prosthesis. If the tissues of the stump have withstood the increased activity of the furlough well, the amputee is given the opportunity of returning to some suitable duty in the Army or of returning to civilian life.

On the patient's return to civilian life his further rehabilitation is taken up by the Veterans' Facility in order that the full meaning of the word rehabilitation, at least from the economic angle, may be accomplished. Prior to discharge from the Amputation Center the patient is interviewed by a representative of the Veterans' Facility and appraised of further educational facilities and compensation privileges. He is also given a booklet which contains instructions in the care of his stump and his prosthesis.

Men who prior to Army service have followed sedentary or mental occupations are able immediately to return to a wage earning status. Men whose previous work has been arduous and laborious will have to be trained in less strenuous vocations. Many youngsters have not as yet engaged in or settled themselves in any type of work. Some of these will go to vocational school, others will take extended training in schools of higher education. Direction in these opportunities is a function of the Veterans' Facility and obviously not a program that can be carried out in a hospital.

The Amputation Center of the Army General Hospital strives to carry rehabilitation of the amputee to the point where he has (1) the best possible stump that surgery can offer, (2) a satisfactory, comfortable prosthesis, (3) skill in the use of this prosthesis, (4) the capacity to meet the routine demands of everyday life, (5) a healthy outlook to the future, (6) a desire

to overcome his handicap, and (7) information as to where and how he may obtain help in becoming an independent economic unit.

HARRY MOCK (Chicago, Ill.): I talked with Colonel Hilldrup just before this meeting, again begging him to find a place for me in this war. Colonel, in spite of what you say about my age, in spite of what they have told me in Washington, I am still in this war! Charlie was one of my boys. I cannot tell you how thrilled I was when I saw Charlie in the movie. He depicts the spirit of rehabilitation which we fought and bled for in the Surgeon General's office and throughout the Army in the last war.

I daresay, Colonel Thorndike, that you will have the same problems we were confronted with in the last war: a sort of half-hearted acceptance of your program on the part of the medical officers; a reaction against the sentimental ideals embodied in rehabilitation and usually expressed by the more hard-boiled officers as, "O hell, we're fighting a war!" This lack of enthusiastic co-operation is the hardest thing to overcome in such a program, whether you call it "rehabilitation" or "reconditioning."

Twenty-six years ago, almost to the day, I talked on this subject before the open forum of The American Medical Association here in Chicago. The Auditorium Theater was crowded. President Wilson's pledge to the disabled soldiers that they would not languish in old soldiers' homes, but rather they would be rehabilitated and made fit for work once more—useful economic units of society in spite of their disabilities. Our program of physical reconstruction and rehabilitation was outlined to the audience. It went over big with the civilians. It was accepted half-heartedly by the Medical Department of the Army.

We went to work on the plan and had to work faster in the last war than you have had to work in this war, because our time was shorter. Within one year after the United States entered the last war we had a fully developed program of rehabilitation working. We found that it had to start in the hospitals with the soldiers when they were first wounded; the spirit of rehabilitation had to be inculcated into those men early, the spirit of rehabilitation as depicted by Charlie.

We found that to get the best results the men must get away from the hospital as soon as possible, and carry on in convalescent centers. As a result, we soon had nineteen convalescent centers scattered over this country within the year, and in those nineteen convalescent centers we were doing the things which you have depicted as your program, Colonel Thorndike.

The occupational therapy there consisted largely of good, sound, manly mechanical work: automobile repair, not radio then but wireless work, typing, telegraphy. We placed 106 telegraphers with Western Union before the Armistice was signed.

Reconditioning, we called it then "redevelopment," also had its place in our program. Every cantonment had its redevelopment center where the

soldiers, not truly hospital cases but still not quite fit for regular service, were assigned for reconditioning. In these centers were the asthenic individuals, the flat-feet and other foot problems, the low back pains (because then the herniated disc was unknown), and similar conditions. Many of the regular Army officers, and even many of the Reserve Corps resented these innovations. A foul trick almost disrupted the usefulness of these redevelopment centers. Some high official secured a general order, placing all of the venereal cases in the redevelopment centers, and the morale of many of these centers immediately sank to zero. In spite of this, the idea was sound, and your present reconditioning program will prove its soundness.

Limited Service was born in the last war. I still have the original memorandum presented to the Surgeon General through Colonel Frank Billings, pointing out that "physical qualifications plus occupational qualifications should equal the job;" that I had an able-bodied surgeon as a stenographer who was crazy to go overseas and fight and who could have been replaced by a handicapped young lawyer from Philadelphia, who was a good stenographer and anxious to be in uniform; that tens of thousands of slightly handicapped individuals had been rejected in the draft examinations, who could be classified for limited service, thus freeing many an able-bodied soldier for overseas front line duty. The plan was accepted by the general staff. A camp was established in Syracuse, New York, and 50,000 rejectees from the draft were ordered to Syracuse. Here medical officers worked in conjunction with personnel officers. These men were re-examined and were classified as follows:

Class A, fit for overseas duty; Class B, fit for overseas limited duty back of the line; Class C, fit for limited duty in this country; Class D, unfit for any type of duty. B and C Class men were then examined by the personnel officers and were assigned to duty according to their qualifications. Three months before the Armistice we had sent 10,000 B Class men overseas, and 30,000 C Class men had replaced able-bodied soldiers in this country.

The day of the false Armistice I was in a meeting with Colonel Love, of the Surgeon General's office, the Assistant Secretary of the Treasury, who then represented the Veteran's Bureau, and two personnel men from the general staff. We were rounding out a plan for retaining illiterates in the Army until they could read and write. Already, in the redevelopment centers and in the convalescent centers, schools for the illiterates had been established, but the true Armistice ended this program. Many in those days frowned upon these innovations in the making of soldiers. Let us hope that this humanitarian viewpoint is more acceptable in the present Army.

In June, of 1942, I went to the Surgeon General enthused with this memory of the work Colonel Billings and my other associates had done in the other war. Of course, some plan of rehabilitation must be contemplated.

The Surgeon General turned me over to a colonel, the colonel turned me over to a major, and the major to a captain, and each time I heard the same story, "We are not going to do that stuff in this war; such work as this will be turned over to the Red Cross."

The present Surgeon General, General Kirk, has been in charge less than a year. I take my hat off to him because he has seen the vision and has established in this country, in this military Army of ours, a rehabilitation program that is equal and is going to be far better because of additional time, than the one we had in the last war. It is hoped that every medical officer in the Army and in the Navy will get behind such a program whole-heartedly.

Rehabilitation is a spirit. It is hard to define. You just felt it when you were thrilled by watching Charlie in the movie. This soldier of the last war, who lost both his arms, is one of the outstanding examples of rehabilitation. Enthused over my work with the disabled soldiers, in the Spring of 1918, I felt that I had taught this spirit of rehabilitation. It came over me in the middle of the night and I got up and wrote the Creed of the Disabled:

> Once more to be useful;
> to see pity in the eyes of my friends
> replaced by commendation;
> to work, produce, provide;
> seeking no favors and given none;
> a man among men in spite of this physical handicap.

Colonel Thorndike, your presentation of the present plans for the disabled soldiers indicates that you have grasped the spirit of rehabilitation. As an old soldier fighting in this same department in World War I, I wish you the greatest success in your program.

HENRY C. MARBLE (Boston, Mass.): The question that comes to some of us now is that we must have more data to go beyond this. These boys discharged from the Army with one arm or one leg are physically handicapped. They go looking for a job. In theory the job is open, but in practice the door is often closed. The man who has the key to the door is the president of the corporation, and he is the one who shall say whether or not that door shall be opened.

He often calls upon his friend, the man with whom he plays golf, or his family doctor, for advice. His family doctor, his friend, you and I, may be of a great deal of value to him in advising him to open that door so these men can go back to work.

With this in mind I tried to find out if I could what the hazard is of these men. Are they a hazard? We all say no, they are not a hazard, but we really do not know.

After a good deal of research I have found two institutions, one in Pennsylvania in which they employ none but blind people, and another institution in New Jersey in which they make a practice of employing none but cripples.

Where did I get the facts? I went to the insurance company that insured the crippled people and I said, "What is the experience?" I went to the company that insured the blind people and said to them, "What is your experience?"

For a basis of comparison, let me tell you that in an ordinary machine shop employing normal persons they pay in compensation insurance approximately $1 per $100 payroll. Employing normal persons, doing light machine work, they pay $1 per $100 of payroll. The institution for crippled men (I remember these figures) in 1938 paid $1.40 per $100 payroll and they had nothing but cripples. That was in 1938. In 1939, they paid $1.25, and the last figures I could get were for 1943 and showed that they were paying approximately 70 cents per $100 of payroll.

In other words, there is a machine shop in New Jersey which employs none but cripples, who in 1943 have 30 cents credit over a machine shop employing normal people.

I hand that on to you so you may have it to answer the gentleman who comes to you and says, "Shall I open the door?" The experience of the blind factory in Philadelphia is comparable.

In Philadelphia they have two parts, one who makes furniture and uses machinery for making furniture, and the other that does weaving. I have never visited the institution, but I am going to. The highest experience that those blind people have had in the last ten years has been about $1.25 per $100 of payroll, and every man in the institution is blind.

COL. AUGUSTUS THORNDIKE (closing): I wish to thank these discussers. They have given me a beautiful creed to work under now. I shall use that, Dr. Mock.

I want to explain, however, the difference between a veteran and a soldier patient. The soldier patient coming back from overseas is often referred to as the veteran. In legal terminology the veteran is the discharged soldier. He comes back from overseas into our hospitals and is still a soldier patient.

The Veterans Administration is responsible for vocational training; the Medical Department is not. That is the law. We have a very close liaison with the Veterans Administration in placing opportunities before the soldier while he is still in the hospital so he can obtain this vocational training. The Veterans' representative visits with him while he is a patient, discusses with him where he lives, what opportunities for vocational training are available in that neighborhood, and arranges all the details for him if he so desires to partake of vocational training.

The other problem of placement of what we term the limited duty soldier, the man who is disabled in part but sufficiently disabled so he cannot do full military duty, is this: We have placed in our hospitals members especially trained from the Adjutant General's department, classification officers, who are capable (with the professional staff) of determining what particular type of duty this man with this individual disability can perform in the Army. That is a new step. It is only just being put into effect, and classification personnel are being carefully trained by the Adjutant General to do this.

I will close by saying that I think I have told you all that we are doing now. We are training these men in these schools to go back into the hospitals or into the centers so that they will know what a patient is. The difficulty has been that the physical training, particularly, has been done by noncommissioned officers who have handled normal men, and they think that these trainees are like normal men. Well, in this school we teach them exactly what they can do and what a patient is.

REPAIR OF CRANIAL DEFECTS WITH TANTALUM

MAJOR FRANK H. MAYFIELD AND CAPTAIN LOUIS A. LEVITCH
MEDICAL CORPS DENTAL CORPS

ARMY OF THE UNITED STATES

SURGEONS have long sought a satisfactory material for the repair of cranial defects. In 1670, J. van Meecran[1] reported the successful use of dog bone for this purpose. A review of the literature by Grant and Norcross[1] in 1939 revealed that many different materials have been utilized. These included animal and cadaver bone, and autogenous osteoperiosteal grafts from virtually every possible donor site, and many foreign materials such as gold, platinum, aluminum, silver, and celluloid. Since 1939, the use of vitallium,[2,3,4] ticonium,[5] plexiglas,[6] and certain acrylic resins have been described. While many of these have proved reasonably satisfactory, none have all the properties that should be inherent in the ideal substance for cranial repair.

Such a substance should not produce inflammation or foreign body reaction when implanted in tissue. It should have strength equivalent to that of the skull, yet it should be malleable to permit molding with reasonable ease, and should not be resorbed. Tantalum more nearly meets these requirements than any other material yet used in surgery.

Burch and Carney[7] introduced tantalum into surgery in 1940, using it in the form of bone plates, screws, and as suture material. Their experiments and clinical observations, and those of Burke[8] proved conclusively that tantalum induces less tissue reaction than any other metal. Pudenz[9,10] was quick to appreciate its potential value in neurosurgery and began experiments to test its usefulness as a material for repair of cranial defects, and also as a hemostatic clip. It is now in general use in the Army and Navy for cranioplasty.

Tantalum is a metallic element, the seventy-third in the periodic table. It is bluish-grey in color and is malleable and ductile. It was so named by its discoverer, Ekeberg, because of his tantalizing experiences trying to dissolve it.

Since January, 1943, it has been used by us to close cranial defects in twenty cases. The oldest case has been done seventeen months,

the most recent only one month. The follow-up is too brief to permit final conclusions to be drawn, but the results have been sufficiently encouraging, we believe, to warrant recording, especially since they

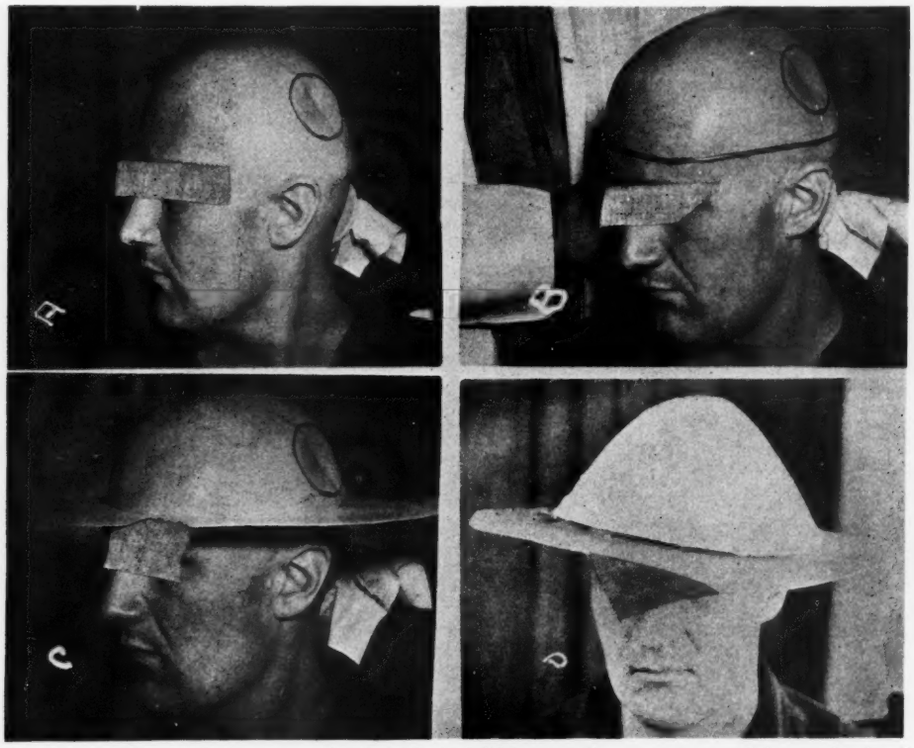

FIG. 1. A, size and shape outlined with indelible pencil. B, contour of heat obtained with flexible lead wire. C, Base-board for plaster. D, plaster impression of calvarium.

are in substantial agreement with those of many others whose work is not yet published.

The purpose of this paper is to present the data from the twenty cases referred to and to describe a technic of preparation and insertion of the plate.

INDICATIONS FOR OPERATION

The indications for repair of cranial defects are: (1) Anxiety due to fear of trauma to the brain; (2) the syndrome of the trephined which consists of headaches and dizziness with change of position and with cough, and of extreme intolerance to vibration; (3) unsightly deformity; (4) defects that pulsate unduly or are painful; and (5) protection from trauma.

Grant and Norcross[1] list epilepsy, when that disease arises from the injury, as an important indication. Our experience is not in accord with this.

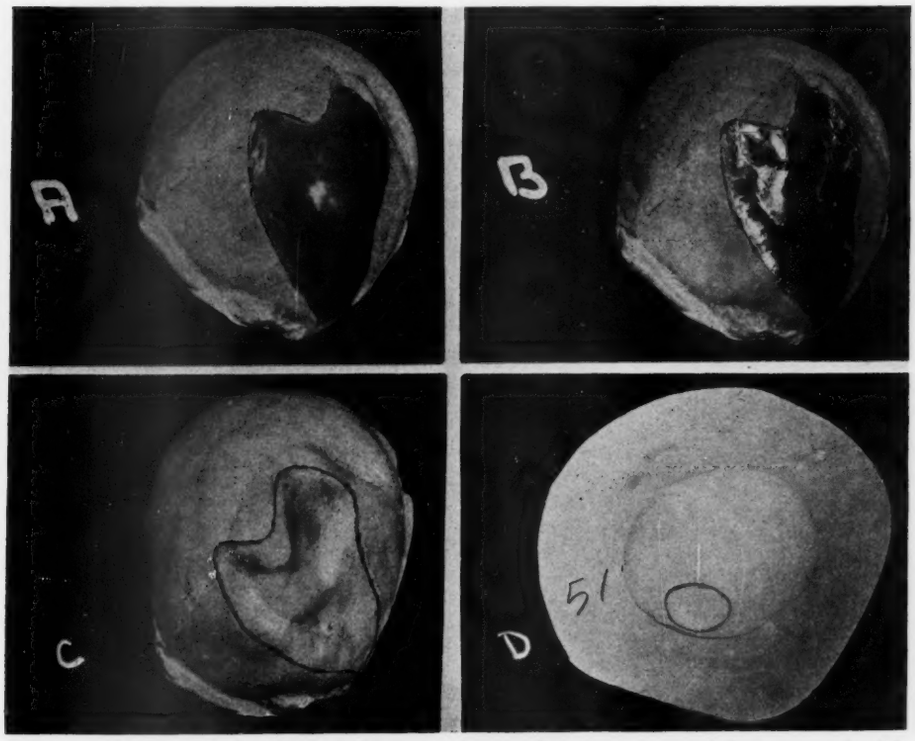

FIG. 2. A, defect filled with dental wax and carved symmetry. B, defect covered with silver foil to facilitate separation of wax. C, outline of defect on skull. D, outline of defect transferred to plaster impression.

Contraindications to operation are the presence of infection or a recent history of sepsis and disease that may lead one to anticipate further surgery of the skull or brain in the area.

It is, however, unnecessary to repair many cranial defects that are small and which cause the patient no concern.

PREPARATION OF THE PLATE

Though tantalum may be molded at the operating table, the procedure is time consuming and the cosmetic result is not always good; therefore, the plate is prepared in advance. In earlier cases plates were formed by hammering. More recently a modification of the press and dye principle developed by McCall has been used. The plate can now be prepared quickly and fits more exactly.

Baker[11] has demonstrated that this method can produce plates of the most complex pattern with great accuracy.

From a plaster of Paris impression of the skull deformity, a

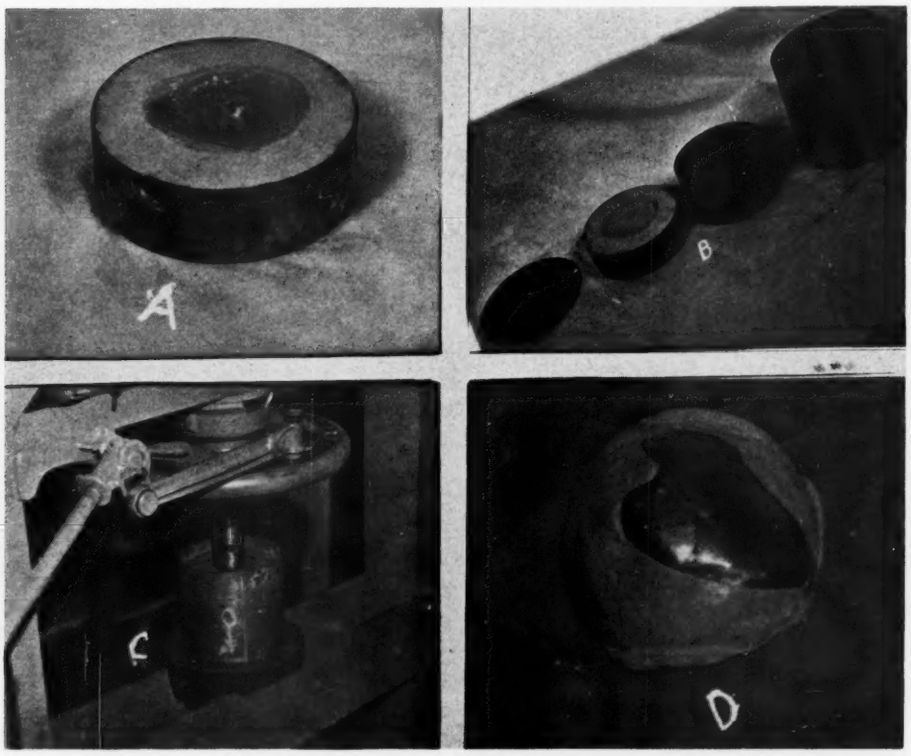

FIG. 3. A, female mold in dental stone. B, metal flask, rubber pad, female mold, pressure plate. C, screw jack press. D, completed plate on plaster model.

female mold of the desired size and shape is prepared of dental stone. The mold is placed in a metal flask and covered with a sheet of tantalum cut to shape with approximately ½ cm. overlap. The tantalum is then covered with a heavy rubber pad and by means of a screw-jack press the plate is molded. Plate of .0125 to .025 inches provides adequate strength yet molds easily. The details of the technic are explained in the titles of the illustrations. (Figs. 1, 2, and 3.)

OPERATIVE TECHNIC

The defect is exposed through a scalp incision planned to consider the healed scar. The prepared plate which bears many perforations is then fitted over the defect. (Fig. 4.) The edge of the

plate is crimped to fit into a shallow groove in the outer table, the groove encircling the defect. This groove may be cut quickly with a high speed dental burr or with a chisel. While the cosmetic effect

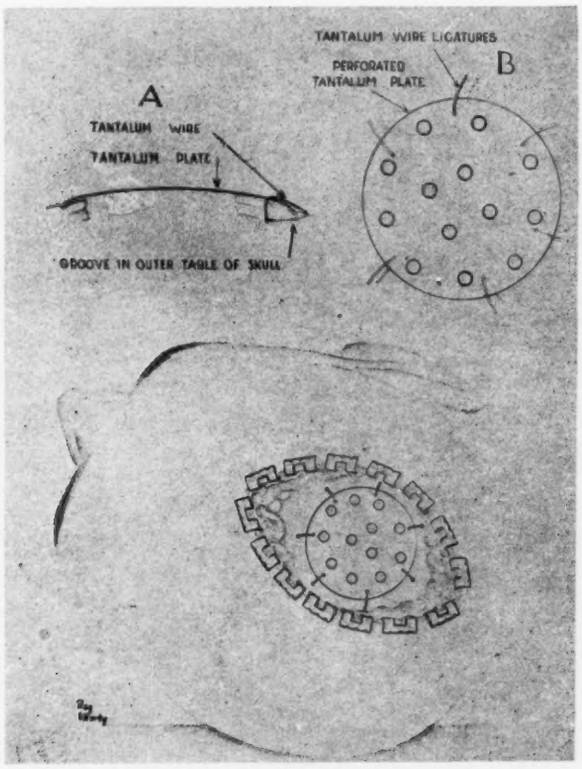

FIG. 4. Diagram illustrating insertion of plate.

is satisfactory when this is omitted, pressure from the hat band or from massage will occasionally cause irritation.

The plate is fixed securely in place with twisted loops of tantalum wire which engage through small drill openings that extend through the outer table of the skull. It is planned that the plate will overlap the defect by ½ to 1 cm.

Spurling and Homburger[12] fix the plate in place with glazier's points of tantalum. We have felt that countersunk tantalum screws would be ideal. Unfortunately, these are not available in correct size.

The scalp is closed with silk in most instances, but in certain cases in which the risk of infection was considered great, a single layer of tantalum wire sutures have been used. Healing with this method of suturing has been most pleasing.

Control of troublesome oozing is sometimes difficult, but the importance of a dry field cannot be overemphasized.

Cranial defects are for the most part traumatic in origin. Less

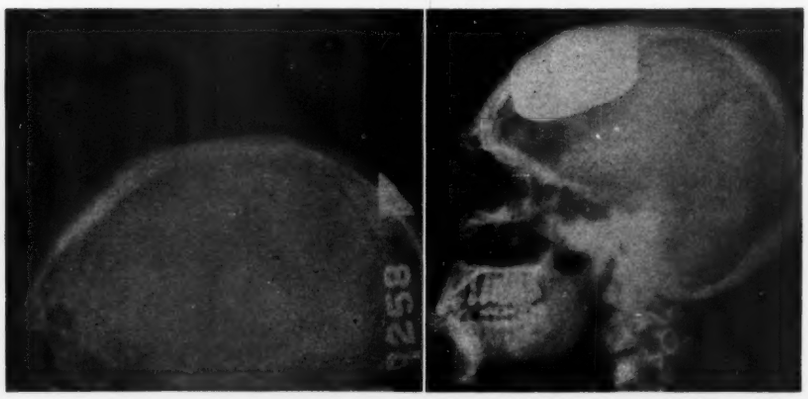

FIG. 5. Left, *x*-ray showing osteoma of skull. Right, *x*-ray of solid tantalum plate in place.

FIG. 6. Postoperative photographs of patient shown in Figure 5.

frequent causes are surgical removal of neoplastic and infected bone. Where skull substance is sacrificed to cure neoplasm, the plate may be inserted immediately. (Figs. 5 and 6.)

Traumatic defects that have not been infected are often repaired within two to three months after healing. Where serious sepsis has been present, we have heretofore required that all drainage have ceased for at least six months before operation. With the advent however of the sulfa drugs and penicillin, we have ventured to

operate within three months after drainage in two cases. One of these, and one clean case, have become infected. These will be reported in some detail as they demonstrate the importance of perforations in the plate.

FIG. 7. Left, preoperative photograph; right, postoperative photograph after insertion of perforated plate. Solid plate had been removed because of infection.

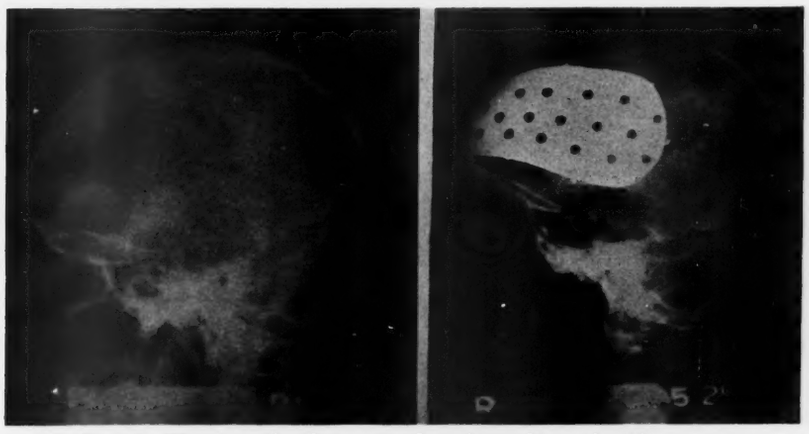

FIG. 8. Photograph of *x*-rays of patient shown in Figure 7.

CASE REPORTS

CASE 1. A twenty-eight year old private lost a large segment of the right frontal and temporal bones when struck by a machine gun bullet. Suppuration of the wound developed and drainage persisted for five months, during which time three operations were done for osteomyelitis. There had been no drainage for five months when cranial repair was under-

taken. The defect was covered with a solid tantalum plate, even though a droplet of pus was encountered beneath the scalp. A quick smear of the pus had shown no organisms, but culture recovered the non-hemolytic staphylococcus aureus. Sulfadiazine had been given preoperatively as a prophylactic and this was continued.

The scalp wound healed per primam and the patient appeared quite well except for a slight but persistent elevation of temperature. It was necessary to aspirate straw-colored fluid from beneath the scalp for a few days. Thereafter the scalp appeared adherent to the plate. At the end of a month redness of the overlying skin appeared and again a few cc. of straw-colored fluid were obtained on aspiration, from which was recovered the non-hemolytic staphylococcus aureus. Previous aspirations had been sterile. Incision and drainage was carried out and penicillin therapy was instituted locally and systematically. Within one week all redness and inflammation was gone and the patient's temperature was normal. Signs of infection re-appeared promptly, however, when penicillin therapy was discontinued. Eight weeks after operation the plate was removed. Approximately 3 ounces of thick yellow pus was found entrapped between the plate and the dura. Prompt healing of the wound occurred with continued penicillin therapy.

Six months after healing the same plate, now perforated, was re-inserted. Convalescence in this instance was entirely uneventful and now, six weeks after operation, there is no evidence of inflammation and the scalp is firmly adherent to the plate. (Figs. 7 and 8.)

Comment. It is believed that had the original plate been perforated that adequate drainage would have occurred and that penicillin therapy might then have been effective. Also, it is believed that the likelihood of suppuration would have been reduced because of the improved blood supply to the infected area.

There has been one other infection in the twenty cases:

CASE II. A twenty-six year old private had sustained a depressed fracture of the frontal bone at the age of fourteen. Drainage had persisted for several months, but thereafter the wound had remained healed. The patient had continued to complain of pain in the area of the depression which also caused moderate disfigurement in that the patient was partially bald.

Nevertheless he had, over a two-year period, maintained an excellent military record. He had fought with credit through the entire North African operation, reporting for sick call the first time two days after the Tunisian campaign ended. His complaints were intense pain in the region of the depressed fracture and of profound nervousness. The pain became an obsession and it was decided upon the advice of the psychiatric depart-

ment to elevate the depression. Attempts to mold the bone into normal shape resulted in its being shattered and the defect was covered with a tantalum plate.

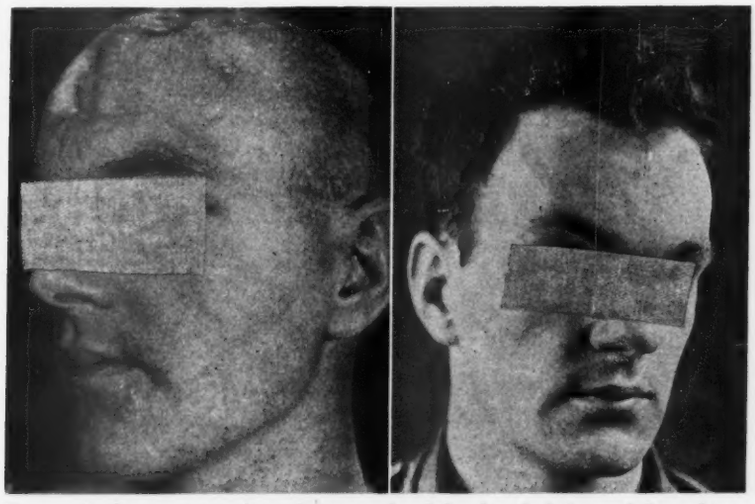

FIG. 9. Left, preoperative photograph of forehead defect; right, photograph six months postoperatively revealing no evidence of dimpling.

Within twenty-four hours after operation the wound showed signs of sepsis and the temperature was elevated to 104°F.

The incision had been in the form of a flap and the two lateral limbs were promptly opened, permitting the escape of copious amounts of serosanguineous pus from which hemolytic staphylococcus aureus was recovered. Under local and systemic penicillin therapy all drainage had ceased within two weeks and healthy looking granulations were covering the plate which had been widely exposed at time of drainage. The wound has now been healed for five months.

Comment. It is believed that in this instance the perforations permitted drainage and more effective therapy and promoted healing by permitting granulating buds to come up from the dura through the perforations.

It is likely that the infection in this case developed as a breach of technic at operation; however, the possibility that bacteria may have lain dormant in the previously infected wound over many years cannot be ignored.

The objection has been raised by some that perforations might cause disfiguring dimpling of the skin if used over the forehead. Figure 9 shows a case in which a large plate with many perforations was used to close a defect of the forehead. A photograph taken six

months after operation, shows no evidence of dimpling. Furthermore, the patient wrinkles the skin of the forehead normally which indicates that a minimal amount of scar tissue is present.

All plates have been prepared with multiple perforations 3 to 4 mm. in diameter and in no instance has dimpling been noticed in patients who have been followed as long as twelve months.

The scope of this paper does not permit discussion of the various cerebral lesions that will be encountered in patients who have cranial defects. Decision to repair such a defect can be made only after thorough study relative to the underlying brain.

Of the twenty cases here reported the defect was traumatic in seventeen; one resulted from the operative removal of a tumor of the skull; one followed the elevation of an old depressed fracture; and one resulted from the sacrifice of a bone flap at an earlier operation due to osteomyelitis of the skull.

All patients were men. Four were officers and sixteen were enlisted men. The oldest was thirty-two years of age, the youngest nineteen, the average twenty-four. Eighteen of the twenty cases healed promptly without evidence of inflammation or infection. Two became infected; these have already been reported. In two patients retained foreign bodies and extensive cerebral scars were excised at the time of insertion of the tantalum plate. Two patients have had epileptic seizures. One developed attacks prior to operation and these have persisted. One other had his first seizure four months following operation.

Four patients who suffered with the syndrome of the trephined have been completely relieved of symptoms. (Figs. 10 and 11.) All patients have been relieved of the anxiety due to the fear of trauma. Two patients have been returned to duty. Ten have been discharged from the service because of disability other than the cranial defect. Eight are still under observation.

With the exception of the two patients in whom wound infections developed, healing has been prompt and the appearance of the wound as satisfactory as if no foreign body had been implanted. Occasionally, it has been necessary to draw fluid from beneath the scalp for two to three days and in two patients moderate subgaleal hematomas occurred which were controlled by aspiration also within three days.

Patients with a large dead space between the plate and dura have been kept in bed ten days with the site of operation dependent.

All others have been allowed out of bed from within four to five days. All are kept under constant observation for at least two months before discharge.

FIG. 10. Left, preoperative photograph of patient with syndrome of the trephined, relieved after operation. This syndrome is more frequent in patients with defects over vertex into which the scalp recedes. Right, Postoperative photograph of patient with syndrome of the trephined.

FIG. 11. Left, preoperative photograph of patient with syndrome of trephined; right, postoperative photograph of patient with syndrome of trephined.

SUMMARY

The data from twenty cases in which cranial defect was repaired with tantalum have been presented. The technic of preparation and insertion of the plate has been discussed.

CONCLUSIONS

1. Tantalum more nearly fulfils the requirement of the ideal material for cranial repair than any other material now in use.

2. The plate should be perforated.

3. The plate should be anchored securely in place over the defect with its edge seated into a groove in the outer table of the skull.

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DISCUSSION

John Raaf (Portland, Ore.): When Major Mayfield asked me to discuss his paper I could think of no good reason for doing so for I have had no experience with tantalum. Tantalum and pantopaque are still not available to civilian surgeons and those of us on the outside are very envious of our military colleagues.

I have used vitallium plates to close cranial defects and have been pleased with the results. I am thoroughly convinced that large cranial defects are more satisfactorily closed with metal plates than with any other type of material such as celluloid or bone.

As Major Mayfield has pointed out it is important to have holes through the plate. If holes are not placed in the plate, serum may collect beneath, elevating the plate. Also the holes allow tissue to grow through the plate and hold it solidly in place.

The splits in the plate are also important because they allow the surgeon to modify the shape of the plate at the time of surgery whereas if the plate were solid it would be too rigid to bend. Vitallium skull plates are not as brittle as I at one time thought. A vitallium plate can be cut with a pair of tinsnips and molded into shape with a pair of pliers at the operating table. Vitallium, however, is not as pliable as tantalum.

I have heard that tantalum will disappear when *x*-ray therapy is given. I do not understand the process and would like to ask Major Mayfield regarding this point.

I agree that if the patient with a skull defect has convulsive seizures the repair of the defect by means of a metal plate will not alter the occurrence of the convulsions.

HARRY MOCK (Chicago, Ill.): I wish every man, every father and mother, could visit these general hospital centers and witness what I witnessed at Percy Jones Hospital just a week ago.

It was the most thrilling experience of my professional life to see all of these head injury cases gathered together there in two wards, to see 250 amputation cases, scores of osteomyelitis, fifty or so nerve injuries, and to see the care that these boys are receiving, to see the anxiety on the part of the medical officers not to have infections, and to get the best results. As I say, it was one of the most thrilling experiences I have ever had.

I visited Major Mayfield's wards and saw practically every one of these cases that had the tantalum plate repair. Most of you know my interest in skull fractures. I was especially interested in these cases. I think he has developed, with the other men in the country who are using it, an excellent method of repairing these defects, and one that will be a great contribution to surgery.

The opportunity of handling a great number of cases, such as they have, will put it across much faster than the here-and-there treatment by some of us individuals in civil life.

I just want to congratulate Major Mayfield upon his paper, but more upon the excellent work that I saw him doing over at Percy Jones.

COLONEL LAURIE H. MCKIM (Royal Canadian Army Medical Corps): I should just like to ask Major Mayfield one question: I have been informed that tantalum is now being used in the method that he has described, but also in various other parts of the body in the form of wires, tubes, and so on; I have also been informed that it is particularly susceptible to overheating by diathermy.

I would like to ask Major Mayfield whether he has any information on that subject, and also on the story that Dr. Raaf has just spoken about, concerning its behavior under the *x*-ray.

MAJOR FRANK H. MAYFIELD (closing): Dr. Venable and his co-workers have proved the value of vitallium in surgery. While vitallium produces a

greater tissue reaction than tantalum, the difference is not great enough to be of any practical importance. Vitallium, however, is not malleable and, for this reason, is not readily adaptable for cranioplasty. Cranial repair often requires plates of complex patterns.

In reply to Dr. Raaf's question, I would say that I have no information which leads me to believe that *x*-rays will dissolve tantallum in tissues. If this is a fact, I am not familiar with it.

Colonel McKim's question as to diathermy is a very pertinent one and this property of tantalum for a while caused us considerable concern. Diathermy will heat any metal, particularly the edge of a thin plate, for the discharge of an electric current from a metal plate is at the edge. This is the principle of the electrosurgical unit.

We have run certain clinical experiments on members of the staff, which consist of holding bits of tantalum encompassed in the palm of the hand while exposing the hand in a diathermy field and there is no appreciable heat if the metal is thick. If the metal is thin, such as in the case of foil, the margins become quite hot, and if the metal is allowed to remain exposed without being encompassed in the hand, the margins become red hot and disintegrate with fire. This, however, is true also of silver and other metals. Since tantalum implanted in the tissue will be bathed in tissue fluids, it is unlikely that any tissue damage will result from the application of this mode of therapy. Nevertheless we do not use diathermy on anyone in whom any metal has been implanted. The patients who have such implants are advised of this potential risk when they leave our care. I should add that there are certain experiments underway which will solve this question.

COMPOUND FRACTURES OCCURRING IN THE ARMY

FACTORS INFLUENCING TREATMENT

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THE present war has increased discussion of the methods of treatment of compound fractures. Articles which seek to apply civilian experiences to the care of war wounds often show an incomplete understanding of the fracture problem in the Army. The character and mechanism of the injuries incurred in various types of service must be appreciated so that treatment methods may be planned to insure maximum benefit to the most severely wounded man.

In order to point out certain factors which influence the treatment which may be given an injured soldier we have reviewed the compound fractures seen by us in three different installations. The first group of cases were from a replacement training center. No heavy weapons were in use and the training was largely concerned with the handling of Signal Corps equipment. During a period of eighteen months twenty compound fractures were operated upon in the hospital. Falls from poles caused four of these injuries, the usual result being a fractured tibia and fibula. Car accidents accounted for five cases. Only one soldier was shot during training. Crushing injuries sustained in falls beneath freight cars necessitated partial amputation of three hands and one foot. The following cases are representative of the group:

CASE I. A private sustained a compound fracture of the lower end of the right tibia and fibula in a fall from a telephone pole. He was treated by immediate débridement and irrigation. A vitallium plate was applied to the tibia with as little disturbance to the periosteum as possible. Sulfanilamide was dusted in the wound and primary closure done. The fracture healed without complications and the patient returned to duty.

CASE II. A private was struck from behind while pushing a stalled car. He sustained a compound fracture of the lower third of the right femur, a compound fracture of the head of the right fibula, and a severe wound of the popliteal space with severance of the popliteal vein and the peroneal nerve. He was admitted immediately, treated for shock, given

500 cc. of plasma and careful débridement was done. The wound was packed with vaseline gauze and a well padded cast was applied. Twenty-four hours later the foot showed dry gangrene. Edema and crepitus in the leg sug-

FIG. 1. Case III. A, roentgenray at time of injury.

gested an early gas bacillus infection. A flapless amputation was performed, and examination of the vessels in the popliteal region showed complete obliteration of the lumen of the artery by clot. Twelve days later the wound was inspected, found clean and healing well. The amputation was revised and the wound healed without infection.

CASE III. A private fell from a pole and sustained a compound fracture of the tibia and fibula. He was treated by débridement and plating of the tibia, vitallium screws and plate being used. Primary closure was done. Twenty-four hours after operation he developed respiratory distress, petechial hemorrhages on the skin, and severe mental confusion. The diagnosis was made of the presence of fat emboli. The patient made a complete recovery and returned to duty. One year later a sinus tract developed near the lower end of the plate. The plate was removed but only after the screw heads were broken off since the screws could not be dislodged from the bone. The patient again returned to full duty.

None of these wounds became infected, although prior to the issuance of specific instructions against the procedure primary closure was used when there was no skin loss, the wound was clean,

FIG. 1. Case III. B, roentgenray thirteen months after injury.

and immediate treatment could be instituted. The healing in these cases did not differ from that expected in simple fractures. Note, however, that few of the cases showed more than moderate contamination. Every case reached a well staffed operating room where definitive treatment could be given within an hour of the time of injury. The injured came in singly allowing the expenditure of sufficient time, help, and thought to select the most appropriate treatment. In the case with the popliteal vessel damage constant observation was possible and justified an attempt to save the leg.

Except in the cases requiring amputation there was no gross soft tissue damage or severence of major nerves.

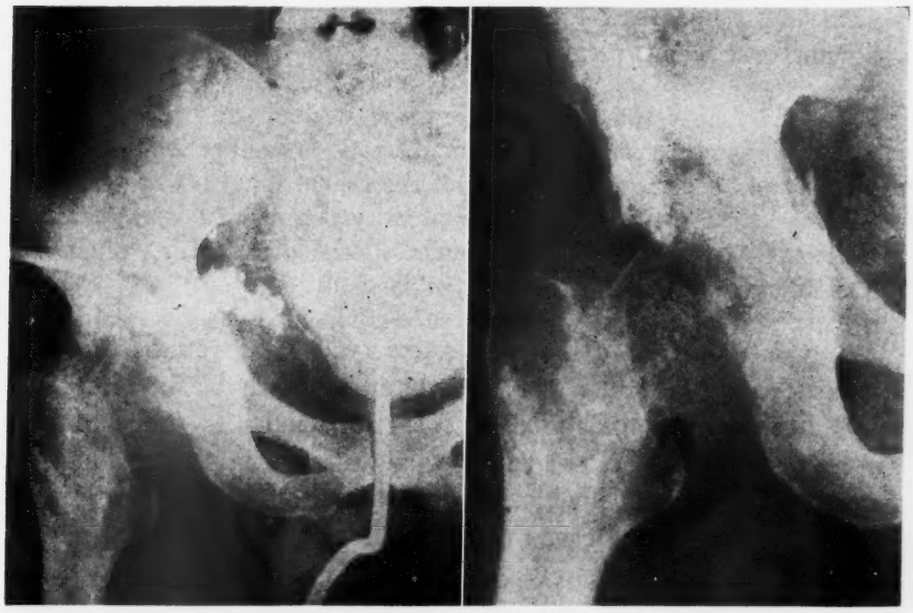
This is civilian type practice at its best. The results show only

FIG. 1. Case III. C, roentgenray fourteen months after injury, showing shafts of vitallium screws broken off in the bone cortex.

what happened under ideal circumstances. They are no aid in planning the treatment of war wounds.

The compound fractures incurred in a mountain training center were of a distinctly different character. Certain injuries were peculiar to the type of training given. Winter brought severe skiing injuries. One soldier, caught in a snow slide, was thrown violently against a rock at the bottom of a slope and received a compound fracture of the tibia. It was ten hours before his arrival at the hospital. In spite of this, treatment consisted of débridement, plating of the fracture and primary closure of the wound. Another soldier struck a snow

covered rock. He sustained a compound, comminuted fracture of the right patella which was treated by débridement and wire fixation. Both of these wounds healed by primary intention.



A B

FIG. 2. Case VI. A, roentgenray taken five months after injury, showing sinus tract through the hip outlined by lipiodol; B, roentgenray of right hip taken eight months after injury.

During the summer months classes were given in rock climbing. Men struck by rock knocked loose by those above them sustained compound injuries of the hands. Others were injured in falls. The following was the most severe injury incurred in this manner and was the only patient who developed gas gangrene:

CASE IV. An instructor fell 35 feet to the base of a cliff where the mule corral was situated. He sustained a compound fracture of both bones of the right forearm. Several hours elapsed before his arrival at the hospital. Prophylactic *x*-ray radiation as well as serum treatment was given as a precaution against gas bacillus infection. Local procedures consisted of débridement, dusting of the wound with sulfanilamide and loose packing of the wound. Forty-eight hours later gas gangrene developed. Wide incisions were made, zinc peroxide was used locally and gas anti-serum and *x*-ray treatment were given. The infection subsided but thrombosis of the vessels in the anticubital space resulted in dry gangrene of the forearm. An amputation was later performed at the site of election above the elbow to remove a useless extremity.

About half of the fractures were incurred under simulated battle conditions. Blast injuries, ranging from compound fractures of the fingers to wounds of the utmost severity were received while attempting to improvise land mines and grenades from dynamite. The following case was typical of this group:

CASE V. A private in the engineer corps, while drilling a hole through a stick of dynamite, sustained compound fractures and partial amputation of both hands, a compound fracture of the right femur and was partially disemboweled. The fractures were treated by débridement and sulfanilamide crystals were placed in the wounds. This soldier died from infection in the abdominal wound.

At this mountain camp it was observed that wounds incurred while the snow was on the ground only infrequently become infected. Snow lessened the likelihood of contamination and the cold permitted the extension of the time period during which wound closure might be attempted. The closure of a wound ten hours after injury, while successful in the case reported, was not wise. There was little likelihood of avoiding infection regardless of the precautions taken in the case of the man who fell into the heavily manured corral. Review of completed cases in which multiple injuries were sustained left the impression that in such circumstances the ideal primary treatment of each individual lesion was rarely possible.

The remainder of our patients have been treated in a general hospital. They arrive from two sources. Some are brought in from nearby camps and airfields and present the same characteristics as those already discussed. They may have had little preliminary treatment or primary care may have been completed. The remainder have been returned from overseas. The majority of the casualties have been injured by small arms fire. These are rifle or machine gun wounds rather than the self-inflicted shotgun injuries occurring in this country, of which we have seen seven instances. These cases illustrate the difference between battle and civilian type compound fractures. The missiles produce bizarre, complicated injuries. There is often damage to nerves without severe injury to closely related structures. One may surmise that had the path of the bullet been slightly different, and had a nearby large vessel been cut, either immediate death from hemorrhage would have resulted or amputation would have been necessary. Men survive with wounds which one would previously have presumed to be almost surely fatal. One case illustrates this:

CASE VI. A sergeant was shot at close range with a rifle bullet which entered the left buttock, penetrated the ilium, traversed the pelvis, and emerged through the right ilium, fracturing the acetabulum and the femoral neck. He was treated immediately by an exploratory laporatomy and suprapubic cystotomy, and was placed in a cast. Six weeks later it was noted that a fistula existed between the bladder and the right hip wound. The hip showed fibrous ankylosis. Ten months after the injury the bladder was opened and a mass of granulation tissue on its right posterior wall was removed. As the tract was curretted it led into a pocket the size of a hen's egg from which a stone was removed. The bladder opening was closed with a purse-string suture, and a suprapubic catheter was left in place. Five days later the tract from the right hip was explored, the hole through the ilium was enlarged and a large amount of necrotic bone and granulation tissue was removed, the wound being then packed open. Healing progressed well for a month. A small amount of urine was then noted to drain from the hip wound. The sinus closed after three weeks and there has been no further drainage. In spite of the severity of his injuries, this man's general condition remains good.

Bullets as well as shell fragments may produce large irregular defects in the soft tissues, and may carry away major portions of the bone. In such wounds any attempt at closure would be futile. The fragments of metal and the sequestrated bone still in the soft tissues when the patients reach the United States show why surgeons concerned with definitive treatment have so frequently condemned attempts at primary closure even though this may appear perfectly practicable to the medical officer giving the primary treatment.

These battle wounds emphasize the necessity for doctors writing on the subject of compound fractures to define the type of case under consideration clearly, both as to the extent of injury and the circumstances of its occurrence. Only this will prevent over enthusiasm for specific types of treatment. Any discussion of the possibility of primary wound closure, backed up by the use of sulfonamides or penicillin must not ignore the fact that casualties are seen by a succession of medical officers and that no record takes the place of daily care by the same physician.

Our casualties are treated in accordance with specific instructions from the office of the Surgeon General. These include adequate exposure with care to avoid over excision of the skin, removal of readily accessible foreign bodies, particles of bone separated from the periosteum, and devitalized tissues. Tight packing of the wound is to be avoided. Later instructions concerning emergency surgery for the extremities have strictly forbidden the closure of any com-

pound fracture of extensive wounds of the extremities. The patients reach the general hospitals in this country in satisfactory condition and radical alterations in the plan of treatment already started are rarely necessary. Except for those patients having injuries of the femur or trunk, most of the men are ambulatory. Their general condition is good and the immobilization routinely used has usually maintained fragments in good position and has afforded relief from pain. Generalized infection is seldom seen and review of the original notes concerning the injuries reveals that a surprising amount of healing has taken place during the period of evacuation to this country.

Fractures of the femoral shaft occasion the most difficulty in treatment. Adequate immobilization for transportation is difficult to attain. During the time necessary to return a man to the zone of the interior there is increased atrophy of the soft tissues, the cast becomes loose, and posterior bowing of the femur is the result. By the time the patient reaches his final destination, the callus may prevent correction by traction or other non-operative methods, forcing a decision to refracture the femur or to accept a poor anatomical result.

Our patients show a high incidence of limitation of motion of the joints, especially limitation of knee flexion and loss of finger motion. Where the medical officer giving the primary treatment has impressed upon the soldier the necessity of keeping his hands mobile there is much less tendency to ankylosis of the joints. Loss of knee flexion is a hazard in any treatment of femoral shaft fractures. Danger of this complication is increased by transportation in plaster, and early joint motion is more difficult to obtain than in patients treated in civilian hospitals. Intensive physiotherapy, when the knee has already lost motion, is hampered by the fact that union may not be solid and that walking can be carried out only in a non-weight bearing calipre which does not permit the knee to be bent.

A few patients have had pin fixation overseas. In addition to the often mentioned danger of non-union, we have noted that the patient is not as ambulatory as he is supposed to be. Fractures of the femur arrive with full hip spicas supplementing the pins. In one instance, generalized edema of the extremity disappeared as soon as the apparatus was removed. This man had shown no more than the usual drainage around the pins. Non-union of a tibial shaft fracture was seen in another patient treated by pin fixation. There had been drainage around the pins but it had not been considered that

dangerous infection existed. A later attempt at bone grafting was followed by osteomyelitis. Since the operative field extended into the site of previous pin insertion the pins are considered the cause of the infection.

We have not used penicillin in the primary treatment of compound fractures or in the initial stages of infection. Our experience with its use in chronic osteomyelitis following fractures has not been great. The cases have usually shown a multitude of organisms in the wound. All sequestra and accessible foreign materials were removed from the wound before therapy was instituted. There has been no instance of a cure by penicillin alone. A distinct lessening of the drainage occurs during treatment even though the predominant organism is not penicillin sensitive. The patients frequently remark that they feel better. Later, drainage may again increase but the general improvement noted makes the treatment of value. Patients who are able to localize their infection, heal up promptly as soon as dead tissue or foreign bodies are removed, even though no penicillin is given. Where, after successful skin closure, bone grafts have been placed in previously infected fields, the use of sulfonamides and penicillin has not always prevented flare-up of the old infection. Their use appears to lessen its severity and may prevent the loss of some of the grafts. Penicillin may not prove a magic drug in the treatment of infected, old, compound fractures.

In the care of battle casualties surgical shortcomings indicate that a team is better than an individual. The army recognizes this, requiring transfer of certain types of cases to special centers. The orthopedic surgeon must frequently call upon the plastic and the neurological surgeon. The closure of skin defects is of vital importance if bone surgery is to be successful and hospitalization is not to be unduely prolonged.

CONCLUSION

Plans for the care of compound fractures must be modified by the circumstance under which the accident occurs, the extent of the injury, and the damage done to structures other than the bone. Experience in the treatment of civilian type compound wounds is only of limited value in planning the care of battle casualties. The necessity of combating the stiffness of joints must be constantly kept in mind. The nerve and soft tissue damage complicating compound fractures show the need of interlocking the so-called "surgical specialties" in order to obtain the best results.

TREATMENT OF FRACTURES IN THE COMBAT AREA

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MEDICAL CORPS, ARMY OF THE UNITED STATES

THE treatment of fractures in forward surgical installations of necessity differs radically in many respects from that which can be undertaken further to the rear. It is difficult for the experienced surgeon, old or young, to realize this at first and to modify his concepts of treatment accordingly. I certainly found this to be true in the North African and Sicilian campaigns. At or near the front there is only one golden rule by which all surgical procedures must be judged, that enunciated by the Surgeon General: "The greatest good to the greatest number." Under this, three guiding principles or objectives must always be kept in mind: You are there (1) to save life, (2) to save limb and (3) to get the patient back just as quickly as you can. Nothing else matters.

Fractures at the front presented peculiar problems. Early and safe transportation is a prime consideration. Secondary only to this, treatment must be designed for the comfort of the patient and the convenience of his handlers. Multiple injuries complicate the treatment. In a large proportion of cases we had to treat not just a badly compounded fracture but a patient with that plus a skull injury, penetrating wounds of the abdomen or chest, or severe lacerations of the other extremities as well. One's ingrained ideas of what constitutes the best fracture treatment have often to be compromised. Care of the fracture must not only be subordinated to care of the patient but must be molded to fit the requirements of peculiar circumstances and conditions.

Lack of equipment is a very real factor in combat areas and he will be most successful who is ingenious at improvisation. At one time I used a broomstick and tentpole as a Hawley table in applying a spica over a fractured femur. (Fig. 1.) The patient's buttocks were placed on the broomstick supported by two up-ended empty medical chests. His crotch was drawn up against the padded center pole as a perineal bar and his shoulders rested on another up-ended medical chest. I knelt on folded blankets on the dirt floor while operating and then rolled a very acceptable spica on the patient

over the broomstick which was later withdrawn. Of course this was not intended as a permanent cast but it sufficed to splint the patient during transportation to a well equipped hospital in the rear.

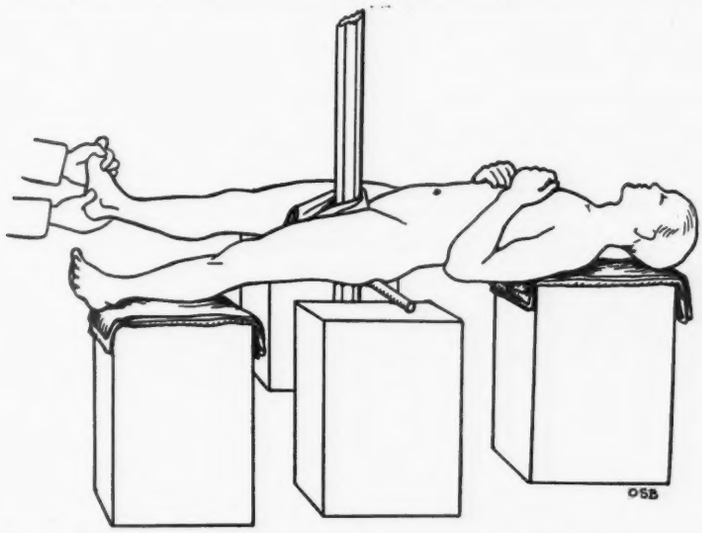

FIG. 1. Position of patient with a fracture of the right femur, supported on broomstick and medical chests, for application of a plaster spica, using the center pole of the tent as a perineal bar.

Similarly, I made a simple but effective Goldthwaite frame for applying body casts and shoulder spicas, using a couple of spring leaves from a wrecked jeep and empty packing cases for a wood base. The ends of the spring leaves I fitted into some old hinges which were pried open and set into each end of the wood frame.

In fact, I designed a basic fracture reduction apparatus in the field and with the aid of a boat maintenance company made it there out of scrap and salvaged metal. It was complete, with pin yokes adjustable in all planes and was open at the base to facilitate *x*-ray and fluoroscopic examination. It was demountable for transportation in a wood case made to fit, with homemade hinges and hasp of brass shell casing. To top it off, this apparatus was chrome plated, when finished, at Oran, North Africa. True enough, I had occasion to use it on only one patient but it was well worth the trouble of making.

A major complication of war fractures of the extremities which we encountered occasionally was tamponade of the circulation from an unsuspected hemorrhage beneath the deep fascia. If the bleeding was from a large vessel, it quickly made itself obvious but in some cases the process was slow or delayed and presented a

most confusing diagnostic problem. I know of at least one amputation for gangrene which resulted from failure to recognize this condition at an early stage.

In many fractures the bone or bones were terrifically shattered and often enough there was a massive loss of soft tissue as well. We tried to save every limb we possibly could but this can be overdone. If, as occasionally happened, the blood supply to an extremity has been hopelessly compromised by injury, necessary débridement or both, it is not only useless but dangerous to temporize by leaving the limb on; amputation should be performed at once. Violation of this principle has been followed by gas gangrene and disastrous results.

In many cases loss of bone as well as soft tissue has been extensive. All the field surgeon can do is to preserve as much as possible and in the case of *bone* this is most important. We are told to remove loose fragments of bone from the wound but at the primary débridement, if there is any question of remaining attachment of periosteum, it is best to leave the fragments in place. Some may regenerate and those that do not can readily be removed later. This brings up the interesting question of what to do with the occasional sizeable fragments that are entirely loose and are removed. Should they be thrown away, as has usually been done, or carefully preserved and sent on back with the patient as potential autogenous graft material? I must confess I have never done this but in an occasional case it might prove of real value.

A word as to casts. It may be that the unpadded cast technic is a good one in well qualified hands *under certain conditions*, but I believe the skin-tight plaster has no place in the primary treatment of battle fractures in the field. Its use there can not be too strongly condemned. Not only is swelling, edema and circulatory embarrassment to be expected in such wounds, but due to the hazards of mass evacuation no adequate check-up on circulation can be expected, let alone guaranteed. For that reason, no matter what has been a surgeon's previous training or experience, all casts applied in this area must be padded, and then they must be split or bivalved throughout their length. The separation must go not only through the cast but through all dressings and bandages underneath as well, right down to the skin itself. This is important, as blood-caked dressings can restrict circulation just as effectively as any type of plaster encasement.

The so-called Tobruk splint for fractures of the lower extremity was quite popular with the British and Canadians and is applied as shown. (Fig. 2.) A long slab of plaster is placed behind the ex-

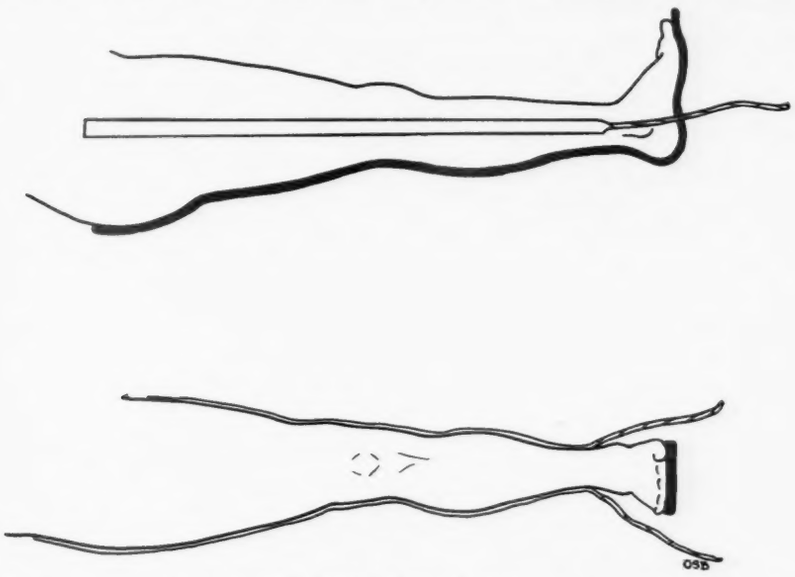

FIG. 2. A, application of Tobruk splint. First stage: posterior mold and adhesive tapes.

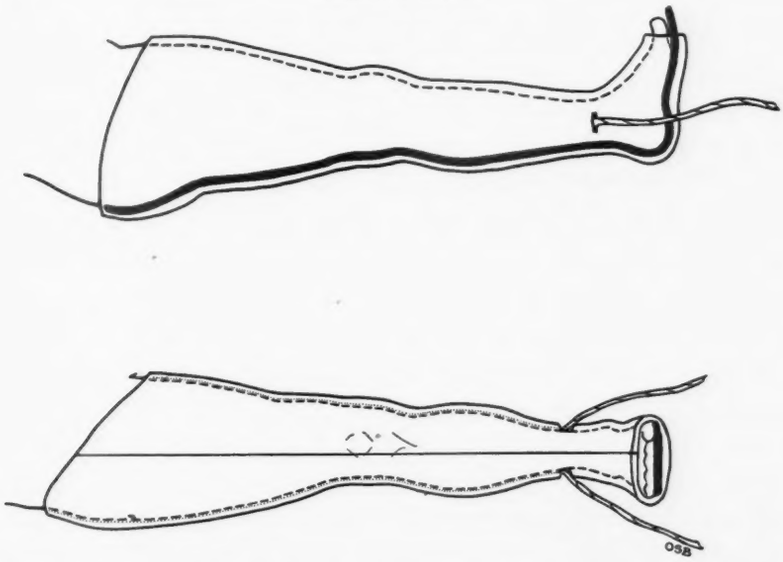

FIG. 2. B, application of Tobruk splint. Second stage: light circular cast, split.

tremity from the toes to well up under the buttock. A three-inch adhesive strip is run along either side of the previously shaved

thigh and leg. Proximal to the malleoli these strips are folded on themselves to make traction tapes. A padded circular cast applied over this is split throughout its length. The traction tapes are led

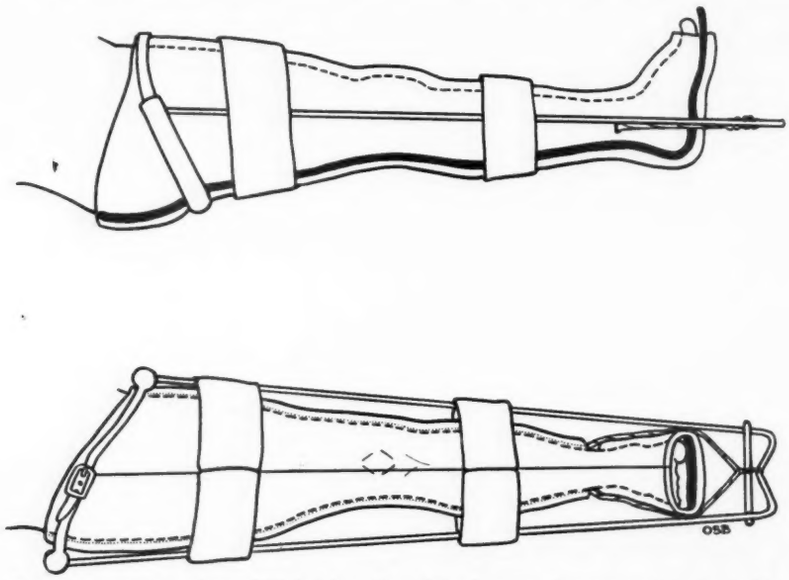

FIG. 2. C, application of Tobruk splint. Final stage: incorporation in half-ring splint with traction.

out through openings left in the cast above the malleoli as the cast is put on. The whole is then incorporated in a half ring splint by a few turns of plaster at midthigh and midcalf. These plaster turns must also be split. Traction is applied in the conventional manner by a Spanish windlass of the adhesive tapes. This type of cast was easy to handle in ambulance or train but in my experience patients were more comfortable in a well applied spica.

Nerve injuries are among the most common and serious complications of war fractures and the possibility of their presence must be kept in mind when the patient is presented for primary surgery. If the case is seen within the first few hours and the ends of a severed nerve can be coapted, this should be done by fine sutures placed in the nerve sheath. Otherwise the nerve ends should be fastened where they are with a small stitch to prevent further retraction and separation.

In the combat area open reduction of simple fractures was not permitted. This was an irksome rule to some of us who were trained in this form of treatment and felt that our surgical judgment was being coerced, but from an overall viewpoint many complications

and bad results were probably prevented by its observance. Compound fractures were another matter. Here the treatment was left pretty much up to the individual surgeon. Yet, as I recall, internal fixation was employed in relatively few instances. One good reason for this was lack of time and the urgent necessity for speedy treatment of large numbers of wounded. Following a careful débridement, thorough lavage of the wound with copious amounts of saline and a loose filling-in with vaseline gauze, most fractures were immobilized for transportation to the rear in a simple plaster cast.

TABLE I
SPECIFIC FRACTURES

	Simple	Compound
Upper extremity		
Clavicle	Figure of 8	Figure of 8
Scapula	Shoulder spica	Shoulder spica
Humerus, head	Shoulder spica	Shoulder spica
Humerus, shaft	Hanging cast	Hanging cast
Elbow	Shoulder spica	Shoulder spica
Olecranon	Circular cast in flexion	Circular cast in flexion
Forearm: 1 bone	Circular cast	Circular cast
Both bones	Circular cast	Plating and circular cast
Metacarpals	Circular cast	Circular cast
Lower extremity		
Pelvis	Double spica	Double spica
Femur, head	Spica or Tobruk	Spica or Tobruk
Femur, intertrochanteric	Spica or Tobruk	Spica or Tobruk
Femur, shaft	Spica or Tobruk	Plating and spica
Patella	Circular cast in extension	Circular cast in extension
Leg: 1 bone	Circular cast	Circular cast
Both bones	Circular cast or Tobruk	Plating and cast unless fragments could be locked
Ankle and metatarsals	Circular cast	Circular cast
Os calcis	Circular cast	Circular cast
Spine		
Body cast, with an extension of molded posterior shell to support the head if the fracture was in the cervical region.		

When some form of skeletal fixation was imperative I preferred plates of vitallium or stainless steel to the Roger Anderson and similar pin transfixion methods as being much quicker, surer and simpler. I found the fracture could practically always be approached by incision through a clean area. The wound of compounding, after débridement, was loosely filled with vaseline gauze and left open.

Counter (dependent) drainage, especially of compound femoral shaft fractures, was often employed with benefit.

Lack of time precludes a detailed description of the treatment given specific fractures but Table 1 shows how the more common types of fractures were handled by us. Bear in mind that this work was all primary combat surgery done under pressure in the field, limited by directives and with the prime objective—cleansing of dirty wounds and adequate immobilization of fractures for prompt evacuation to the rear.

Please observe that we used a great deal of plaster and very little hardware. As a rule these patients reached larger, better equipped installations far to the rear, where definitive treatment of the fractures was undertaken, within one to four days after leaving us. We had good *x*-ray facilities and were usually able to secure a good or fair reduction between immobilization.

Referred pain from fractures was an interesting phenomenon and sometimes followed a bizarre pattern. I remember being called one night to see a patient with a fractured clavicle for an attack of acute abdominal pain. It was both surprising and gratifying to have the abdominal pain disappear and the spastic abdomen relax as soon as a poorly fitting Velpeau was replaced with a snug figure-of-eight bandage. It may be asked why a fractured olecranon was put up in flexion. I can only say that the patient was transported more comfortably in this position and apparently did well subsequently. Plating was not done in every compound fracture of the femur or of both bones of the forearm or leg. Occasionally, extreme fragmentation of bone or the general condition of the patient rendered this inadvisable.

I recall that we used intravenous sodium pentothal more frequently than any other form of anesthesia in treating major fractures in the combat area. There were a number of reasons for this, the most important perhaps being the ease, simplicity and speed with which it could be administered. In the hands of one well trained in its use there was no difficulty in securing muscle relaxation when required and then reverting to a lighter plane of anesthesia for the balance of the operation. I know of only one minor complication from its use, a temporary cessation of respiration, in several hundred cases and heard of no fatalities for which it could be blamed. Next in frequency came spinal anesthesia for lower extremity fractures. This was very effective but was often a bit awkward to administer.

It always seemed much more of a procedure and consumed more time which in a busy forward installation is an important factor. In a few cases in which one team performed a laparotomy while another treated a fracture or fractures on the same patient inhalation anesthesia was employed with benefit. Many simple fractures, such as a Colles, were reduced with novocaine infiltration directly into the fracture site.

Fractures came to us at the clearing station or surgical hospital generally in pretty good condition. Major fractures of long bones almost without exception were well supported in a Thomas splint which had been applied at a collecting station or by litter bearers on the field. It was surprising to me to see this job so well done on such a large scale. Rare indeed was the patient whose splint was improperly applied or on whom excessive traction had been placed. I believe that this early adequate immobilization contributed more than any other one factor to the generally satisfactory results obtained in the treatment of fractures in the combat area. All credit for it is due to the intelligent, well trained and hard working enlisted men of our Medical Corps.

COMBINED DISCUSSION OF PAPERS OF COL. AUGUSTUS THORNDIKE, MAJOR FRANK MAYFIELD, MAJOR W. F. STANEK AND MAJOR B. M. BOSWORTH

Col. Laurie H. McKim (Royal Canadian Army Medical Corps): Colonel Penberthy suggested that we might say something about the program of casualty retraining, as we speak of it in Canada. We have such a program, and it is along almost the identical lines that have been outlined so very ably by Colonel Thorndike.

I was rather disappointed that Colonel Thorndike did not mention one point which we think is of great importance in the reconditioning of men, and that is the effect of getting the ordinary patients, the routine operative patients, out of bed at the earliest possible moment. I think there is no doubt that a review of things as they are today would definitely point out that in the past surgeons as a whole have made a great mistake on two particular points: (1) They have kept their patients in bed too long. (2) They have not fed them soon enough and in sufficient quantities after operation.

I think these two points are being attended to very carefully now, and I am sure the results that are being shown by the early getting up of

patients after hernias, and so forth, will amply justify the work under investigation.

There was one point that I intended to mention. In 1917, at the clearing station, called the casualty clearing station, where I was in France, we had a period in the first of December following the first Battle of Cambrai, during which we had no food except condensed milk, Army biscuit and canned beef. We had about 250 abdominal cases. We had no other food for them for a period of about five days, during which time we were snowbound. The roads were blocked as were also the trains. We had to feed those patients on what we had. They did not care very much about the condensed milk, but they ate the beef and the Army biscuits, and I may say that closures of perforated wounds of the stomach and intestines seemed to do rather well on it. That changed my own ideas as regards early feeding after operation.

In regard to Major Stanek's paper, there are a few points I should like to mention. Major Stanek mentioned that in one of his cases he had gas gangrene. He mentioned that he treated this by *x*-ray. Does Major Stanek think that this *x*-ray treatment is of any value? I wonder what the majority of the members here think. Personally, I do not think it does any harm, but I question very much whether it does any good.

I certainly would like to agree very fully with Major Stanek's statement that the primary closure of wounds in compound fractures is almost never justified.

Finally, I would like to agree with him on one other point, which I think he might have stressed even more strongly, and that is the use of the newer antiseptics, such as penicillin and sulfonamides, should not under any circumstances allow us to take our mind off the main target, which is that these things cannot take the place of adequate surgical procedures.

With regard to Major Bosworth's paper, he mentioned two points that I think are of great interest. One is the slow bleeding in the tissues with obstruction of the arterial circulation. He mentioned this with regard to wounds. We have recently had a series of cases in Canada and the United States in which we have had gangrene of the toes and of the foot following simple fractures.

Some of our friends tell us that this is due entirely to arterial spasm. I just wonder if it is altogether due to arterial spasm, and whether some of these cases of gangrene of the feet, which have been reported following simple fractures of the leg, are not due to this slow bleeding that Major Bosworth has spoken of.

Finally, Major Bosworth has mentioned the question of cutting plaster of Paris casts. We have recently had a very interesting discussion on the returning of casualties from overseas on our hospital ships, and the officer commanding the surgical division is quite firmly of the opinion that by far

the greatest number of casts that he has had to change on this hospital ship have not been due primarily to too tight a cast, but to a circular bandage over the dressing which becomes soaked; the dressing swells, which causes pressure at the site, and ulceration of the skin from the pressure caused by the bandage and not by the actual pressure from the plaster cast.

COL. ROBERT I. HARRIS (Medical Corps): It is a privilege I greatly appreciate to be at this meeting, and especially to be permitted to take part in the discussion of the papers on military surgery.

I realize that you are paying a tribute to the Canadian Army, and I am happy that with Col. McKim I have been chosen to represent your Canadian military colleagues.

Major Bosworth hoped that what he had shown us would bring to the minds of the "oldsters" in the audience memories of the last war. He has done that, but he has done more than that. He has taught us and shown us how much progress has been made in the management of problems which are fundamentally the same now as they were then. There is no question about the fact that we are managing war wounds with much more skill and with much more success than we managed them in World War I.

It would be impossible for me to discuss the program as a whole, and there is nothing that I can accomplish by attempting to do so. But there are some items in the program about which I should like to speak, and the first is Colonel Thorndike's paper on reconditioning.

If my judgment is correct, the work in reconditioning which has been stimulated by the necessities of this war will be one of the great contributions to medicine that this war makes. If you will recall the experience of the last war, there was a great impetus to things that we now call reconditioning. It was so in our country, and I am sure it was so in your country. It was then that physiotherapy and occupational therapy first started and developed.

But the impetus died in the years between the two wars, and there have been periods when those who have been concerned with reconditioning, have been unhappy about the part that physiotherapy and occupational therapy should play.

There seemed to be too much individual treatment, and too much treatment by the physiotherapist or occupational therapist of the patient rather than stimulus to the patient to be his own therapist. That is to say, there was a stress upon passive therapy rather than upon active therapy.

The great stimulus which the needs of this war has given has emphasized this very point, namely, that to get well and to be reconditioned a man must do things for himself. The basis of reconditioning, in your Army as presented by Colonel Thorndike's paper, and as I know it is planned in our Army, is that it shall stimulate the man's own activity. It shall start at the earliest possible moment so that in a large way he will never get into the

state of poor condition which we have been accustomed to allow our patients to reach. He should be taught what he can do for himself; he should be stimulated and coaxed and cajoled to do these things for himself, and he should be urged to become an independent treater of himself under guidance.

This is important and unless we carry it over into post-war problems, we have made a great mistake. It is of tremendous importance, and cannot be done without profound changes in the training of people devoted to this work.

We train physiotherapists, occupational therapists, and instructors in physical education, and physical instructors. But there is no co-ordination between their training, and often the overlap of their fields of activity leads to conflict and confusion.

If the military program of reconditioning which we are setting up is to be of use after the war, it must go back to the very beginning. It must be based upon a broad concept of what is reconditioning. In my opinion it is much broader than can be defined by "physiotherapist" or "occupational therapist" or "physical instruction." There is more to it than all of these put together.

We must think of setting up courses in physical reconditioning which will include all these branches and more besides.

I agree with Colonel Thorndike that for the successful direction of this work in hospitals there is need of medical officers of a particular type. One of the mistakes we made in the last war was to put the work of the physiotherapist and its handmaiden at that time, occupational therapy, in the hands of certain members of the staff already there—usually the surgeon who was interested in orthopedic surgery. It is perfectly true that the orthopedic surgeon has more interest in this than most people; but on the other hand he cannot devote enough time to it, to planning, to directing, to providing the stimulus to his workers and to the patients, without neglecting his work as an orthopedic surgeon.

We have need of specialists in this field, and part of the success of any program of reconditioning will de dependent upon the selection of skillful men properly trained in this field and functioning well after they have been given command of the work.

Major Stanek and Major Bosworth did well to emphasize the difference between the management of compound fractures in civil life and in war. Major Stanek was correct in pointing out that the fractures we see in the Army in training on this continent are in effect the fractures of civil life. They are comparable to severe industrial fractures or severe road accidents. So it would be wrong, as he stated, to draw conclusions and to lay down principles of treatment based upon compound fractures seen in training.

But in the gunshot wounds with the enormous destructive effect they produce, the ever present contamination with dirt, the certainty that the wound is contaminated with bacteria, the stripped-down simplicity of

surgical equipment and the circumstances under which surgery must be performed, if it is to be done at a time when it will be most effective for the patient, all must be treated with the single purpose of combatting infection. That is the first principle. As Major Bosworth pointed out, the first objective is to save life and to save limbs. Under these circumstances it is obvious that we cannot do in the line what we might do in the training camp.

I was intensely interested in Major Bosworth's firsthand account of what he did, in what we would call a Field Surgical Unit but what he calls an Auxiliary Surgical Team. Far too little of this firsthand experience has come back to us as yet. We learn more by such accounts than by anything else.

COL. AUGUSTUS THORNDIKE (Medical Corps): My experience in the Southwest Pacific was that of Chief of the Surgical Service in a large general hospital. It is well, perhaps, to inform the members that the terrain is a little different in the tropical islands than what Major Bosworth described.

We sent out from our hospital two portable surgical hospitals; that is a new unit. It was promulgated in the Southwest Pacific because of the terrain. The surgical portable hospital consists of four officers and thirty-three enlisted men who carry their equipment on their backs. The patients are housed in tents with cots, and everything is carried by pack.

Transportation is different. At the time of the Buna campaign these surgical teams were operating very much closer to the front than what Major Bosworth described, again because of the difficulty of transporting the wounded to the rear.

I cannot describe it too much in detail, as it is a military secret, but you will find in the December issue of the Bulletin of the Medical Department an account of one of my hospitals that was up in the Buna campaign. That is the December 1943 issue of the Medical Department Bulletin.

Those fellows sweated it out, and they did a marvelous job. They came back to us; they looked like different people. They lost a lot of weight; they had been sick all of them, but they carried on. We now have from that same hospital two other units up in the forward area doing the same thing on these islands at Hollandia and other places.

Again it is a question of bringing surgery and the expert surgical care forward to the patient who is wounded in battle.

Might I open the remarks I closed before, prior to some of the questions Colonel Harris raised.

Concerning Colonel Harris' suggestion about training of the occupational therapist and the others in the whole program, the Manual we are now preparing is in three parts. One part is the physical reconditioning; another is the educational reconditioning, which I believe is the most important factor to have been added to this program; and the third part is the occupational therapy.

Those three functions—officers, enlisted men or civilians, and the occupational therapists who are civilians—will all get three parts of the Manual and become acquainted with how they tie in.

In the occupational therapy field there is a great scarcity of personnel. The War Department has approved a new emergency course to qualify, subsidized, in private schools now existing, a four-month course for civilians and an eight-month apprenticeship afterward in certain designated general hospitals. That is the way the Army is attacking that problem.

Concerning Colonel McKim's remark of getting them out of bed early, I did not mention it but we thoroughly approve of pushing a patient through his early stages of convalescence with adequate physical exercise in bed so that he does get out of bed and does progress from the first day very much more rapidly.

I did not mention the military training aspects of the advanced reconditioning section in great detail, but that is really a rugged course in training.

Lt. Col. Richard T. Shackelford (Medical Corps): I hope you will understand that everything I say is my own personal opinion. I cannot back it up with statistics because we have no statistics.

I have been asked to speak about my experience with the so-called combat surgical team which was detached from three of our general hospitals in the South Pacific, namely, the Yale Unit, Hopkins Unit and University of Maryland Unit.

We were assigned to take part in the amphibious landings in the Solomons. Surgery and the surgical care of patients in theaters of that kind is quite different, I gather, at least different from the problems in Italy and Europe. We have no roads, no landing fields, no railroads. It is quite obvious that it is imperative to give complete surgical care, and the best surgical care, on the beachhead on the island at which the landings take place.

There is no road over which to bring back the wounded. They have to be carried back by litter, down a narrow trail, with snipers along the trail. They cannot be evacuated at night. Any man above ground at night is a good target for our men as well as for the enemy.

The work is done in dugouts. If you are lucky you may have a fly tent, but as a rule most of our work was done in a shallow dugout, about nine by six feet in size, covered by a fly tent.

Fortunately, in the landing in which I took part our casualties were less than we anticipated. Also fortunately, the Navy had exactly the same sort of setup that we had, and so the work was not as heavy as we had expected. But there are certain things that did occur to me, and certain things that we learned.

One thing we learned was that abdominal wounds should be operated upon right away—immediately. That is not new. But they should be operated upon regardless of whether the man is in shock or is not in shock. The patients were operated upon with no pulse and no blood pressure. We would get them ten minutes after they were hurt, pulseless and pressureless. We would start plasma in the vein, use ether anesthesia, and that is a point I should like to emphasize: We were all of the opinion that sodium pentothal and spinal anesthesia were contraindicated in the men who were in shock. Most of the patients we got were in shock.

So we started plasma in the vein and started them immediately on ether anesthesia, operated upon them, and on opening the abdomen in the great majority we found active hemorrhage present. If we had waited to give transfusions and various things to bring those chaps out of shock, they never would have come out of shock.

Once the bleeding was stopped with intravenous fluids going through, their pulse began to come back, their blood pressure began to rise, and we could then take our leisure time preparing for the operation on the abdomen, even three or four hours, however serious the case might be.

The second thing that we found, and for which we are hunting a solution (and which was a point in Dr. Loyal Davis' remark that interested me most) was the matter of blood transfusions. Plasma has been miraculous. We owe a great tribute to it and the way it is packaged. You can carry it in your pocket; you can carry it in your pack. That is the way we had to carry things. Our total equipment fitted into two-foot lockers. That is all the equipment we had, that is all we could carry. Each team consisted of two surgeons, one anesthetist and two corpsmen. We had three such teams. That group included one thoracic surgeon and one brain surgeon, but all of us had had general surgical training.

We also carried one laboratory man who was of great assistance because he did the blood groupings and matchings, and we found quite a high percentage of error in the blood groupings that were put on the identification tags that the soldiers carried; so we had to rematch every patient to whom we gave a transfusion.

Using the indirect method of blood transfusion, we found two difficulties: The first one was that in using the ordinary amount of citrate for some reason not known to me or any of us, and the Navy had the same trouble, we found that the blood clotted. We did not know whether that was because blood is more concentrated in the tropics, where everybody is sweating all the time, but we found that we had to use triple the amount of citrate to prevent the blood from clotting.

The second thing we found was that we always got a reaction, and a severe reaction in many instances, so much so that we finally had to abandon the indirect method of blood transfusion and then resort to the

direct method which is nowhere near as statisfactory. In the first place, it ties up three men doing it, and when you are busy you cannot afford to spare three men.

In the second place, with the basins of water down in a foxhole, with various insects of all kinds and lizards and various fauna and flora that seem to abound in that area, we were never quite sure of sterility. But we had to resort to direct transfusion.

It seems to me it would be well for a while, as a project for the National Research Council or any other such agency, to develop a scheme whereby we could have blood and tubing available. Personally, I suspect our trouble was with the tubing. We cannot carry enough distilled water to prepare our tubing properly. But if someone could devise a method which would make the giving of blood as easy as the giving of plasma, I believe our problems certainly would be greatly simplified.

As far as the other treatments of wounds are concerned, they did not differ markedly from Major Bosworth's. We treated compound fractures the same as he did. We débrided them, packed them in sulfanilamide and vaseline and put them in a plaster cast. The plaster cast is a great convenience when transporting men if you have to transport them by litter, which you usually have to do down to a beach and then from the beach put them on either an LST boat or, if you are lucky, make connection with a Dumbo or PBY flying boat, unless the airfield is captured or unless you build your own airfield. The wounded could be put in the planes and transported back to the bases further back.

Concerning soft tissue wounds, we learned one very valuable point from our New Zealand friends. Lieutenant Colonel Wilson, in the New Zealand Army, who had had three years with the 8th Army and who was our fairy godfather in the Solomons, taught us much we did not know about war surgery. He emphasized to us that dependent drainage should be established in all excavated soft tissue wounds. We are quite firmly convinced that Colonel Wilson's point is a good one. So we made a practice of establishing dependent drainage in all large wounds of the soft tissues.

I cannot go further into the medical treatment of patients because I have no statistics and I cannot quote any figures. I wish we had a way, as the New Zealanders have, of following up the patients we operate upon. I do not know whether we did right or wrong in some of the cases. The New Zealanders have a very practical method: They have a perforated tag on the EMT tag, so when a patient is operated upon the surgeon at the front puts his name on the tag. When that patient reaches the base hospital and has his final definitive treatment, the perforated tag is torn off, the diagnosis and result is placed on it, and it is mailed back to the New Zealander who did the original operation. In that way he has some idea of the quality of the work that he has done. Unfortunately we do not. I do not know whether we do well or whether we do poorly.

My last point is that as far as the Pacific war is concerned, with the difficulties in transportation and with the delays made necessary by the fact that you have to wait for airplanes for transportation, or boats for water transportation, you never know when it is going to come; it may be several days or it may be an hour. With those difficulties it seems imperative that we have to supply skilled experienced surgical treatment on the island on which the beachhead is established. With that in mind, it seems to me that there are two places in which experienced surgeons are needed as far as the Pacific is concerned: First, right at the front lines where you get patients five, ten or fifteen minutes after they are hit. I believe if such is provided, a good many patients, particularly those with abdominal or thoracic injuries, will be saved.

I noticed in Major Bosworth's figures only 5 per cent of the cases in the general hospitals were abdominal cases. Our Chief of Surgery of the general hospital located well back behind the lines said we have very few abdominal cases, and the reason, I believe (although I do not know) is that many of those men do not survive.

When we think of the remarkable percentage of wounded who recover in this war, I am afraid those figures are based on the number who reached the hospitals further back, and not based on those who reached the collecting companies.

We were working in collecting companies, and in collecting companies I got the impression that our mortality was higher. I do not have the figures, but I did get that impression.

If we can provide trained surgeons in the collecting companies, the wounded can be operated upon right there, and it is surprising how well they do under the crudest conditions. I was not at all disappointed by the number of infections that we got working under what looked like the most unsatisfactory and septic conditions.

So it seems to me that the place for the great majority of your younger, well trained, skilled surgeons is at the front. Otherwise one rehabilitation surgeon and one specialist in each field is all that is necessary, and their chief job is to keep the younger surgeons from operating too much.

I have heard the argument expressed that if this is done, too many skilled men will be lost. I think that is an exaggeration. Life at the front did not strike me as being any more hazardous than crossing 42nd Street and 5th Avenue in New York. In my opinion the doctors should take just as great a risk as the infantryman.

G. F. Berg (Pittsburgh, Pa.): The last remarks were very well taken. I think the Major should be congratulated on being an expert gadgeteer. By that I mean he was able to judge the situation and take care of that situation With what he had at hand, he was able to devise an apparatus which was life-saving.

There are just a few things I should like to mention: (1) Finger-out or non-finger touch technic in the treatment of any compound fractures. At present you hear very little said about keeping the fingers out of the wound, and allowing only instruments to be handled by the handle, and any part of the instrument that comes in contact with the hand, should not be permitted to enter the wound. I think that over a good many years, the men who have had the most experience and have been trained in that technic, are not nearly so apt to have the wounds re-infected by bacteria placed in the wound as the result of any surgical procedure.

Dr. Leriche called attention in the last war to a type of fracture known as the fissured or the butterfly fracture. An individual who has met with a bad compound fracture, depends upon the original care that he will receive. It has been proved that fissured fractures in which the fissures become contaminated with bacteria or have foreign material forced into them, will develop osteomyelitis unless the foreign material is removed and the fissures thoroughly exposed.

If you take an individual who is in the prime of life, split the periosteum, remove the traumatized or fissured part of the bone, keeping the periosteal tube extended, nature will reproduce a normal shaft. Some individuals think this is not true, but past experiences have proved that nature is remarkable and with proper assistance does some remarkable things. In doing any operation involving a bone, split your periosteum and permit some of the bone to remain attached to the periosteum. I think that every first-aid team stationed near the seat of action, this team being the one designated to do proper débridements of compound wounds, should be provided with good bone holding forceps and three instruments, that resemble chisels. With these it is possible to perform a débridement with dexterity. In removing the periosteum, the tubercle or bony prominence to which muscles are attached should be removed intact with the periosteum.

There is one other thing I should like to call to your attention—the danger factor in the productoin of gas gangrene infection—and that is the inability of the muscular structure to secure sufficient space in which to expand after an injury, unless the fascia which surround it is split.

Major W. F. Stanek (Medical Corps): In answer to Colonel McKim, and not to start a discussion at this late hour, I believe that if I had to give up any one of the treatments used in gas gangrene, I would most willingly give up the *x*-ray therapy.

Major B. M. Bosworth (Medical Corps): In answer to Dr. McKim, I just want to say that I did not see any gangrene resulting from a fracture *per se*, that is, not to recognize it myself.

As regards Lieutenant Colonel Shackelford's discussion which I enjoyed immensely, there are one or two points I think in which my experience differed from his. (1) Receiving the patient in shock and operating upon

him immediately. Our first inclination and action was to do that very thing in the field; but we learned rather quickly that we got better results if we delayed our surgery a little bit and got the patient out of shock, with the single exception of patients with internal hemorrhage. If it continued, of course, we went right into it because there is no use putting blood in one end and letting it flow out the other.

Concerning transfusions, we used the indirect method, the citrated blood, with very great success. Offhand I do not recall a single instance of reaction that we had; but of course we were working under much more favorable conditions. Our tubes could be cleaned and sterilized very well.

Concerning the problem of the supply of whole blood, many of these patients had to have massive whole blood transfusions regardless of the plasma that they had had before they reached us. Plasma certainly combatted and overcame the primary shock, but those patients would sometimes reach us either in secondary shock or about to drift into it.

I think it is foolish to wait for the presence of secondary shock to make obvious the need of whole blood when you know a patient must have lost a quart or more of it before he reached you.

With that in mind, we did establish a donor pool of twenty men in the Quartermaster and Supply services in the rear. Those men were sent over to our outfit up near Hill 609 when we were working there, and every day we had twenty men giving their blood.

We also got hold of an electric refrigerator which we set up in our pharmacy tent, and set up a portable generator so we had a blood bank.

In the clearing station we were still much farther from the front than Colonel Shackelford's front was. We were as far as ten or twelve miles from the actual fighting. We had no cots, merely tents for the men to be housed in overnight, and every morning all patients were evacuated regardless of their condition. When we wished to give a transfusion we had to get one of our own medical personnel to do it. We had no laboratory equipment; in the first place, we depended upon the dog tag, which is fallable. We checked that up with a gross cross-matching on a slide.

THORACIC INJURIES*

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ONLY those thoracic wounds that involve the pleural cavity will be discussed and not those that kill so soon that practically no medical aid can be given.

Some wounds of the chest obviously are extensive and expose the lung and pericardium or other intrathoracic organs. Many, however, are so small that they have an innocent appearance and there may be little external leakage of blood. The importance of this is that in these same patients there may be very great hemorrhage into the pleural cavity, with resulting gradual collapse of the lung on the injured side; as the blood accumulates, a gradual displacement of the mediastinum occurs toward the opposite side, with consequent progressive collapse of the opposite lung. When both lungs are greatly collapsed and the great vessels of the mediastinum are severely pressed upon or kinked, fatal anoxia occurs.

I have just mentioned pressure by blood. Equally important is pressure by air, especially if the air is trapped in the pleural cavity by a wound of the thoracic wall that is so narrow and oblique that the air can not readily escape.

The air may enter the pleural cavity through a wound in the chest or through a wound in the lung, or both. The important thing about such thoracic wounds, especially those with small wounds of entrance in the case of penetrating wounds, or of entrance and exit in the case of perforating wounds, is that at first they appear to be innocent. In the last war little was known about the abnormal physiology of the condition and, therefore, little was done to correct it, and death often occurred. In this war many surgeons have been so well trained that the mortality rate from physiologic upsets of this particular type of wound has been greatly reduced in those patients who are reached by medical aid in time.

Besides those patients having relatively small wounds of entrance, or entrance and exit, such as those produced by bullets or small shell fragments, there is the other type in which there is a large opening of the thoracic wall, so large that air cannot become trapped in the

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pleural cavity but enters and leaves it with approximately equal freedom. This is termed an open sucking wound. If the pleural cavity has not been previously obliterated by adhesions from pneumonia, empyema or some other condition in civilian life, the lung collapses as air rushes in; also, the mediastinum swings toward the opposite side, in which negative pressure still exists, and the lung on that side partially collapses. The lung on the side of the wide opening in the thoracic wall tends to collapse most during the inspiratory expansion of the other lung while, in expiration, the reverse takes place. Air within the lungs is, therefore, shunted back and forth, from one lung to another, and this air rapidly becomes stale air that does not contribute to oxygenation of the blood. Thus, only a part of the force of inspiration is effective in drawing fresh air down through the mouth and trachea and into the bronchi to oxygenate the blood. The mechanism described in this paragraph explains how open sucking wounds may bring about a fatal anoxia, whereas blood or air accumulating in the pleural cavity under increasing pressure brings about anoxia through great bilateral pulmonary collapse and direct pressure upon the heart and great vessels.

The patients of both groups go into apparently typical surgical shock, whether or not there is extensive hemorrhage into the pleural cavity or loss of blood through the wound in the thoracic wall. The causes of this shock are only partly due to the loss of blood (if much blood has been lost) and to the various other factors that customarily produce surgical shock.

In many cases the greater part of the shock picture is due to a special "thoracic shock." This is caused by a specific imbalance of the vital functions of respiration and circulation within the chest. These thoracic factors in the shock picture, which if untreated, are often fatal, usually can be easily relieved by expert and early care.

I cared for many French and American soldiers with thoracic wounds in the last war. The problem of the relief of gravely disarranged intrathoracic physiology was little understood and my patients showed little evidence of having been treated properly, according to modern standards. Those who reached the base hospitals apparently had survived in spite of the unfavorable conditions or because the unfavorable conditions were not grave enough to kill.

In order further to define this condition of "thoracic shock," one may speak of static and dynamic situations. The former is

illustrated by a case in which a certain amount of blood or air, or both, has entered the pleural cavity, collapsing one lung, displacing the mediastinum toward the other side but not sufficiently collapsing the opposite lung to produce a fatal anoxia by the time the hemorrhage stopped. The most frequent way in which the entrance of either blood or air into the pleural cavity is checked is by collapse of the lung containing the leaking blood vessel or bronchus; the pulmonary collapse is brought about by the accumulation of blood or air in the pleural cavity. The loss of blood or air from the lung, therefore, tends to be self-limiting. Whether or not the patient can withstand the intrapleural pressure that finally occurs will, of course, largely depend upon how great that pressure has become.

Open sucking wounds of the chest are the best illustration of a dynamic disturbance of thoracic physiology produced by a war injury. Another illustration is given by the so-called "stove-in" chest in which each of several ribs has been fractured in two or more places and in which the fragments move paradoxically with regard to the respiratory movements, namely, inward during inspiration and outward during expiration.

With regard to the management of the types of injury, perhaps the most important thing is the recognition of the potential seriousness of the situation at a time when the wound may appear innocent and when the patient's condition is good. The distant transportation of a patient who is on the edge of cardiorespiratory decompensation is likely to be fatal if competent care cannot be given during the trip. The danger is especially great if transportation is by airplane and particularly is this so if he should be transported at a sufficient altitude to cause a considerable expansion of a large amount of pneumothorax air within a closed or virtually closed pleural cavity, since the increase in the volume of the air might be enough to produce sufficient pressure on the lung and mediastinum to bring about fatal anoxia. Air trapped in the peritoneal cavity or within the gut or pleural cavity and having no means of escape, expands according to a definite mathematical formula, depending upon the amount of elevation above sea level, and may produce great pressure upon the surrounding organs, which would not occur at ground level.

As to the management of patients having surgical and thoracic shock, the usual measures employed for surgical shock are employed in these patients, as well as the special measures later to be described.

The giving of oxygen is even more important than in non-thoracic cases, because of the direct involvement of the respiratory system.

Diagnostic Signs and Symptoms. A simple physical examination will tell whether there is a tension pneumothorax; there should be absence of breath sounds, displacement of the heart and trachea and, perhaps, dulness over the dependent portion of the pleural cavity, denoting blood. Other signs of this condition are respiratory distress, cyanosis, rapid pulse and irritative cough. If the wound through the thoracic wall is oblique and of the incised type without loss of substance (as may be produced by bullets, small shell fragments or knives), allowing air to enter the pleural cavity more freely than it can escape, a tension pneumothorax results. In such cases, the inspiratory contraction of the muscles surrounding the wound opens the wound to the ingress of air, and relaxation of the wound in expiration tends to trap the air that has been aspirated into the pleural cavity. Similarly, certain wounds of the lung permit the escape of air into the pleural cavity during the act of inspiration and prevent the return of the air into the bronchial tree during expiration when the lung and its wound edges collapse.

If the tension pneumothorax was caused by a valvular wound of the thoracic wall, the wound should be plugged or tightly strapped as a first-aid measure and then the air that had accumulated in the pleural cavity should be promptly aspirated in order to cause the collapsed lung to expand and share in respiratory function.

One should be prepared to aspirate the air repeatedly, because, as I have said, the air may have entered the pleural cavity not only through a wound in the thoracic wall but also through a wound in the lung. The plugging of the wound in the thoracic wall will not in itself prevent the continuing enlargement of the pneumothorax through a wound of a bronchus if this should be present. Failure to aspirate as often as necessary is an important cause of death in this particular group of patients. If a patient must be transported without facilities for aspiration en route, a catheter should be introduced obliquely through the thoracic wall into the pneumothorax, and the outer end of the catheter extended so as to lie beneath sterile water in a jar placed dependently with respect to the patient's chest.

As soon as adequate operation room facilities are available, the tight pack in the wound should be removed, preferably during positive pressure anesthesia, the wound débrided and sutured air-

tight and any pneumothorax air aspirated. The patient should be urged to cough in order to keep open the airways, as many patients have injuries of the lung and retained blood and secretions in the bronchi. If necessary, postural drainage and intrabronchial aspiration by catheter or bronchoscope should be used.

When the damage to the thoracic wall or lung, or both, has been extensive, the chance of severe infection of the pleural cavity is lessened if the pleural cavity is drained dependently by the water-seal method *at the time* the wound of the thoracic wall is débrided and sutured. Drainage should not, of course, be used unless injured pulmonary vessels are sealed.

In the early part of this war there were, and still may be, some enthusiasts who urged early major exploratory operation through a long incision to remove foreign bodies and blood clots and to suture the lung or resect a damaged part of it. Experience has shown that this is unwise and leads to poor end results, including a higher mortality rate, as compared with the conservative measures I have described, namely, débridement and layer-by-layer suture of the wound, and dependent water-seal drainage of the pleural cavity to take care of potential infection and of a continued leakage of air from the lung. The conservative management gives the patient an opportunity to adjust derangements of his cardiorespiratory physiology which an early major operation might greatly accentuate.

Early, wide thoracotomy is, of course, indicated under certain circumstances, which include thoraco-abdominal wounds, continuing severe hemorrhage from the thoracic wall, lung or mediastinum and, perhaps, large retained foreign bodies. Prerequisites for such an operation should be a surgeon experienced in thoracic surgery, good positive pressure anesthesia, adequate instruments and a clear idea, on the part of the surgeon, of what he expects to be able to accomplish.

If foreign bodies, whether large or small, have not been removed from the lung, pleura, mediastinum or muscles within the first three or four days after injury and if serious infection has already developed, they should not be removed until several weeks or months have passed and until normal physiological conditions of the chest have been re-established, and preferably not until infection has been controlled.

The management of hemothorax deserves special attention. Most of the blood may enter the pleural cavity from the wound of

the thoracic wall; if the hemorrhage from this source is large, an intercostal or internal mammary or other vessel may require ligation. The most frequent source of a large hemothorax is, however, a wound of a pulmonary vessel. Mention has already been made of the self-limiting character of such pulmonary bleeding. The blood accumulating in the pleural cavity collapses the lung and thereby compresses the bleeding vessel which, being in the pulmonary circuit, has a blood pressure that is only one-fifth that of the systemic circulation.

If an exceptionally large accumulation of blood should occur before a pulmonary vessel becomes closed, the hydrostatic pressure of the blood against the heart and great vessels of the mediastinum, as well as mediastinal displacement, may produce cardiorespiratory decompensation. In such circumstances, the hydrostatic pressure must be relieved but the collapse of the lung must be maintained for the few days necessary to permit the formation of a firm thrombus in the injured vessel. This may be accomplished by the aspiration of 200 or 300 cc. of blood and the immediate injection of approximately the same amount of air, or a less amount. This sequence of aspiration and injection should be repeated until the ill effects of the hydrostatic pressure have been relieved.

Air replacement of hemothorax blood should not be used in situations other than that outlined in the last paragraph because the air rises to the top of the pleural cavity where it prevents the desirable early expansion of the lung and its adherence to the thoracic wall. If infection should be present in the pleural cavity, the injection of air would push away the lung from the uppermost thoracic wall (if the hemothorax had not been sufficiently large to do so) with resulting infection of the upper, as well as the lower, pleural cavity. An infected superior pneumothorax is usually difficult to obliterate. If an infected hemothorax is treated by aspiration and later tube drainage, without air injection, as civilian empyemas are treated, the uppermost lung quickly becomes adherent to the thoracic wall, and the lower part of the lung which was collapsed by the empyema pus gradually becomes expanded and adherent, from above downward, until no open pleural space remains to harbor pus and pyogenic organisms. These are the reasons why the often recommended routine of air replacement of hemothorax blood is likely to be harmful and to result in prolonged disability.

Three, four, or five days after the formation of a traumatic hemothorax, there is little danger that the thrombosed pulmonary vessel will bleed again if the blood is gradually aspirated and the lung thereby expanded during a period of several days. In many cases the hemothorax can thus be completely evacuated, because blood in the pleural cavity tends to remain fluid. If, however, the pleural cavity is exposed to a broad area of traumatized thoracic wall or lung, the blood is likely to clot and, then, only pockets of serum can be aspirated. Also, if a hemothorax is infected, masses of fibrin and pus cells permit only partial aspiration of the contents of the pleural cavity. Organization of blood sediment or clots or the débris of an infected hemothorax results in a mass of contracting scar tissue which holds the lung rigidly, restricting respiration and pulling in the ribs. Such patients become "thoracic cripples," being dyspneic on exertion and suffering pain because of the strong pull of scar tissue on the thoracic wall and diaphragm. Furthermore, a chronic empyema, with thick walls of scar tissue, is difficult to cure. The sequelae of unaspirated hemothorax are, perhaps, the most important cause of prolonged disability among the wounded men who have been sent to the base hospitals in this country with thoracic wounds.

The characteristics of hemothorax just described make clear the importance of early, staged aspiration of all fluid blood that can be withdrawn. Even when no infection is present, delay in aspiration may result if the partial sedimentation and subsequent organization of that part of the hemothorax blood that does not become absorbed. We should, therefore, reject the advice often give that hemothorax blood should be aspirated only when it is producing pressure symptoms.

In cases in which clotted blood or an infected hemothorax prevents emptying of the pleural cavity by aspiration, there is an increasing tendency among the thoracic surgeons who see the patients within a month or six weeks after they have been wounded, to open the chest and manually to remove the masses of organizing blood clot and débris. The operation may include the stripping of a layer of organizing material from the visceral pleura so that the lung will be able to expand; this procedure is termed pulmonary decortication.

The therapeutic results of thoracic injuries in this war are remarkably good and are infinitely better than they were in the last

war. During the last war I spent most of my time removing shell fragments from muscles and lungs and combating pleural and pulmonary infection which was almost always present. The knowledge thoracic surgeons acquired from the thoracic wounds of the first World War and from experience in civilian thoracic surgery conditions during the following years has led to measures that often effectively correct disturbances of thoracic physiology and that bring about early complete expansion of a collapsed lung, which is probably the most important factor in preventing prolonged disability from infection of the pleural cavity.

DISCUSSION

CASPER P. HEGNER (Denver, Colo.): Dr. Alexander is not only a pioneer but he is the man who has stimulated and trained more men in doing thoracic surgery than any other person in the United States.

He has well said that the thing peculiar to thoracic injuries is due to the small margin of safety under which the thoracic viscera function. We, therefore, have disturbances of the physics and physiology of the intrathoracic viscera, particularly the lungs, also the heart and the circulating blood. If a surgeon attempts to do anything in the treatment of these injuries, he must remember the peculiar conditions presented only by the intrathoracic viscera.

Dr. Alexander emphasized the point that the external evidence of injury is no index to the severity of the internal damage. Therefore, one should not attempt any definitive treatment unless environment, facilities and personnel are qualified to meet every contingency that might arise.

We see that not only in hospital practice but in our part of the country where we have people who, injured by automobiles, have crushing injuries of the chest, with pneumothorax and hemothorax. These patients are delayed in being brought to the hospital for their definitive treatment, and the individual who first saw the patient either attempted too much or did too little.

The question about pneumothorax is an important one. We know we have a closed type which may be simple, and not disturb the patient very much. But if it is recognized by the surgeon and he attempts to do something to that, he may contaminate and infect the patient.

The pneumothorax must not be disturbed unless it produces definite dyspnea, respiratory or circulatory distress. In the type of tension pneumothorax which increases in magnitude and pressure with each respiration, it must be relieved on the spot.

I would offer a suggestion more efficient than repeated needle aspiration, that is, insert only a hypodermic needle and relieve the pressure

constantly, just in proportion to the increase; if it is very great, a larger caliber needle might be introduced. If there is any fluid there, tie over the end of that needle a thumb cot or a rubber glove finger which is slitted so it can be a valve which will let the pressure out as well as facilitate drainage and not let any air in. That will take care of the tension pneumothorax that originates from the bronchial side of the injury.

In open pneumothorax the dangers increase in direct proportion to the size of the opening and the length of time it remains patent in an individual. For instance, a man had part of the side of his chest shot away by a gunshot wound while crawling through a fence. The wound was so large that you could put your two fists into it. Fortunately, he was within half an hour of the hospital and was brought in. While we were preparing to do something for him in a definitive way we covered him with a wet towel. You would be surprised how quickly he was relieved of his dyspnea.

Dr. Alexander mentioned anoxemia. That can be very rapidly fatal. We know that it can also be chronic and can cause a patient to lose ground gradually, and you will not be able to explain it. The exchange or the interchange of air from the good side into the lung of the injured side accounts for that because it does not get enough oxygen to supply the requirements of the body.

The shock accompanying these injuries is not only due to the injury itself, but it is also due to the alteration of the mechanics by which the heart cannot supply sufficient blood thoroughly oxygenated to the vital centers of the brain, and therefore that must be controlled by closing off the open wound.

The hemothorax may come from the wall vessels, intercostals, internal mammarys or the subpleural, and that is progressive and goes on and will become fatal unless it is taken care of. Those patients require operation. Those which come from parenchyma, as Dr. Alexander has well said, are controlled by the fact that the lung collapses, but it may become massive. Hemorrhage in the hemothorax should not be aspirated until and unless the respiratory distress and dyspnea become so great that you have to relieve the pressure.

It should not be aspirated for several days; and when you do aspirate it, aspirate it and replace it with air. I know this is a moot question, but it takes care of the intrathoracic tension, and air is absorbed much more rapidly than fluid.

The question of clotting of blood is a very peculiar one and is not thoroughly understood. The more slowly blood accumulates, the more likely it is to coagulate. Blood in any amount in the thoracic cavity is a nidus for infection. It supplies a splendid medium for bacteria, and it is better to aspirate (when you do) all the blood and replace it with a corresponding amount of air. This will eliminate that condition favorable to bacterial growth.

Dr. Alexander, of course, did not have sufficient time to go into all the details. We appreciate what he has said. There is much more to be said about thoracic injuries than his time permitted. The little points I have brought out I have used in civilian practice, and I know it would be much better to put in a needle than to have a bottle hanging by your side when transporting an individual from the front lines to a base hospital or to a hospital in the rear. The house staff does not appreciate that they have to reaspirate to relieve tension promptly. They may come late and will find the man almost in extremis; but if they put in the needle and cover it with a piece of gauze, this will answer very well.

COLONEL GROVER C. PENBERTHY (Medical Corps): Dr. Alexander has emphasized the need for the early recognition of tension pneumothorax, hemothorax and the methods to be employed in dealing with such serious complications of chest injuries.

It is important and imperative that the complications of chest injuries be recognized early as described in this presentation. The interest shown by the thoracic surgeons, combined with the surgical teams that have been organized and functioning, as explained and referred to by Colonel Shackelford, offers security from the point of view of dealing with chest injuries near the front. It is apparent that the officers have an understanding of the physiology, mechanics and pathology of chest injuries.

The chest cases that I see on rounds visiting the general and station hospitals in this country throughout the Seventh Service Command are well handled indicating that the officers have been trained in the fundamental principles of thoracic surgery. As a result, the mortality from empyema, for instance, in this war is minimum and practically nil as compared with that of World War I.

FROSTBITE

CLASSIFICATION AND TREATMENT

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WHEN human beings are subjected under unfavorable circumstances to temperatures below those to which the body is accustomed, frostbite results. Exposure to moderate degrees of cold for a prolonged period will produce lesions identical to those seen in persons exposed for a short period to an extreme degree of cold. The duration of exposure is as important in the production of lesions as is the degree of temperature. Thus there is a time temperature factor.

The presence of moisture, as in immersion in cold water or standing in wet trenches, is an almost equally important factor. There is ample clinical evidence that the presence of moisture hastens the onset of the lesions. Experimental evidence confirms this belief. The work of Smith, Ritchie and Dawson[10] proves beyond doubt that the lesions occur with less severe degrees of cold when the tissues are wet. The experiments of Lewis and Love[15] indicate that this is due to the phenomenon of "super cooling." Obviously, lack of or inadequacy of protective garments, is an important factor. Clinically and experimentally, there is ample evidence that constricting garments are harmful. Immobility is also an important factor.

Exposure, under unfavorable circumstances, to extreme degrees of cold for prolonged periods may lead to death before tissue reactions occur. There are numerous known cases in which the entire body has been found completely frozen. Where death does not occur before tissue reaction sets in, typical lesions develop. These lesions are identical whether frostbite is or is not accompanied by immersion, or whether it follows exposure for a relatively short period to intense degrees of cold or for a relatively long period to very moderate degrees of cold. Failure to recognize these facts has led to much confusion. Larrey,[1] in the Napoleonic wars, saw and recorded large numbers of cases of frostbite. They were observed and recorded in successive military campaigns. In the Balkan Wars, where men

were exposed in wet trenches to moderate degrees of cold, frostbite was prevalent. Because actual freezing temperatures did not occur, the true nature of the lesions went for a time unsuspected and infected rye bread was for a time suspected of being responsible for the occurrence of gangrene. Page[8] pointed out that cold was the important factor. In the first World War similar lesions were encountered in the trenches. Clinically, the lesions were identical with those classified as first degree frostbite. Because more serious lesions did not occur there was again doubt as to the real nature of the lesions; but Smith, Ritchie and Dawson[10] in their excellent experimental studies showed that cold was the most important factor, and recommended that they be classified as frostbite. In the present war large series of cases have been recorded following shipwreck. Clinically, all these cases would seem, from the published reports, to be identical with cases recorded in our series. The majority of the cases have come from the North Atlantic where temperatures at or near the freezing point prevail; but cases of the mild type, which would appear to be similar to our first degree cases, have occurred in the gulf stream at temperatures ranging from 50 to 70°F. It must be noted that these temperatures are far below the normal temperature of the human body, and under unfavorable conditions with lack of adequate protection, with prolonged immobility, immersion in water far below normal body temperature, and prolonged exposure, frostbite results. In the Southern United States similar lesions have been recorded[31] under similarly unfavorable circumstances.

Whatever may be the contributing factors the lesions of frostbite are similar in all groups of cases. Any portion of the body may be subjected to actual freezing and tissue reaction will follow, but exposure to cold, not sufficient to cause death, typically results in the occurrence of lesions in the extremities. The ears and tip of the nose are often, but much less frequently affected. We believe that lesions occur in these tissues because here the ratio of mass to surface area is least and heat loss from these tissues is consequently greatest. The lower extremities were more commonly affected in our series and here second and third degree frostbite was common. The lower extremities were in every serious case immersed in water in the open lifeboats. The upper extremities, in a considerable number of cases, showed first degree frostbite although these extremities were not immersed.

In a previous communication[32] we have presented a study of seventy-one cases seen in shipwrecked mariners. Since then additional cases have been seen bringing the total number of cases to ninety-eight. A few of the later cases were in patients in whom no immersion occurred. Clinically, the cases were essentially similar. Our observation of these cases obviously led to the conclusion that they fell into three broad groups—the mild, the moderate and the most severe—and suggested a classification into first, second and third degree frostbite depending upon the severity of the lesions. The essential features of the three groups are summarized in the accompanying table (Table 1):

TABLE 1

Degree	Local Condition	Constitutional Reactions	End Result
First.....	Swelling of affected extremity with pain, redness and increased temperature; in more severe cases bleb formation	Slight; fever of 99 to 100°F. common; subsides rapidly	In less severe cases restitution to integrity of parts with no disability; in most serious cases prolonged disability with stiffness of affected parts and persisting pain; no tissue loss
Second...	In addition to those above dry gangrene of the most distal portions of extremity; in mild cases, of terminal phalanges only; in more severe, of digits and in most severe of more distal parts of foot or hand	As above	Loss of digits or of distal portions of foot or hand
Third....	In addition to lesions proper to degrees to 1 and 2 extensive gangrene involving more proximal portions of extremity, often of incomplete or wet type, extending in the lower extremity above the ankle to the knee or even to the thigh	Severe prostration; high fever	Loss of limb

PATHOLOGY OF FROSTBITE

Since frostbite in the human patient results either in restoration to integrity of the tissues affected or to the complete death of the

tissues, with or without the complication of infection, pathological material from this source is of little value in arriving at any understanding of the mechanism by which the tissues are destroyed. Gangrene whether caused by cold, by other trauma, or by primary disease of the vascular system is essentially the same process—death of tissue. Thus, Brahdy, in a recent and excellent article on frostbite, gives an account of the pathological changes observed in tissues removed four months after the onset of the condition. These consisted of atrophy of the skin, necrosis of bone, production of granulation tissues or fibrous tissue and the presence of organized thrombi in vessels. These studies are certainly of great interest. They do not, however, offer much that is of value when we are faced with the problem of what we should do about the treatment of these conditions. Tissues removed surgically represent the end result of the changes initiated by physical agents. They give us no insight into the early tissue changes which are of paramount importance. We must, therefore, turn to experimental pathology if we are to gain an understanding of the sequence of events when tissues are subjected to extreme or prolonged exposure to cold.

In this connection we are most fortunate. Two studies of inestimable value are available. One by Richspler[3] deals with the effects of freezing on animal tissues. The other by J. Lorraine Smith, Ritchie and Dawson[10] studies the effects of moderate but prolonged exposure to cold and wet upon animal tissues. The first study closely reproduces the conditions under which humans experience has been considered as true frostbite; the second study reproduced the conditions observed in successive military campaigns, and which during the first world war was christened "trench foot," but which we now have seen in shipwrecked mariners far removed from the comparative security of trench warfare.

Richspler[3] subjected animal tissues to freezing by a mixture of ice and salt and observed the tissue changes after varying periods of exposure. He found that all of the phenomena observed were due to inflammation caused by cold. Early edema resulted; the bundles of connective tissue were swollen; the muscle fibers of the vessel walls showed early vacuolation; the changes in the nerve fibers were not marked and were not constant; there was little or no evidence of thrombosis in the vessels.

Richspler was compelled to conclude that the formation of thrombus was secondary to inflammatory changes in the vessel

walls and that no significant changes in nerve tissues could be observed. Here then is a compelling similarity to the pathological changes observed by a second group, namely, working on tissues subjected to cold under dissimilar conditions, but under conditions exactly simulating those encountered both in trench warfare and in our group of cases among shipwrecked mariners. (J. Lorraine) Smith, Ritchie, and Dawson[9,10] give an account of their observations on soldiers invalided from France suffering from trench foot and of experimental studies on rabbits subjected to exposure to moderate cold and standing in mud of varying degrees of moisture. By this means they were able to reproduce in the shaven extremities of rabbits lesions identical to those observed by them in soldiers. Their experiments were conducted in the laboratories of the Royal College of Physicians in Edinburgh upon the request of the National Insurance Medical Research Committee and arose out of the prevalence of frostbite among the members of the British Expeditionary force to France during the winter of 1914–1915.

I shall not attempt to give in detail the experiments carried out nor the detailed histological findings in the tissues studied. It is necessary, however, if we are to gain an understanding of the nature of frostbite to review briefly their more important findings.

The temperature of the chamber in which the experiments were conducted was about 0°C. They definitely established that moisture hastened the onset of damage to the tissues. They also were able to show that constriction of the extremity hastened the onset of tissue changes. Interestingly enough, anesthesia developed early in the tissues as evidenced by absence of the pinch reflex.

Grossly, the tissues responded by edema. Sections of tissues obtained soon after the development of edema showed no changes in the larger vessels. The smaller arteries and veins and the capillaries showed enlargement of the endothelial cells of the intima and infiltration of the perivascular tissues with polymorphonuclear and mononuclear cells. In the neighborhood of the vessels the connective tissue cells were swollen. Generally, the connective tissues showed edema with plentiful deposition of fibrin most marked beneath the skin papillae. No hemorrhage was observed in the connective tissues. In the epithelial tissues perinuclear vacuolation with some mitosis in the cells of the germinal layer was seen. Nerve tissues showed no change. A few isolated staphylococci were noted in the subepithelial connective tissues. Sections of the popliteal glands also showed

changes, notably dilatation of the central sinuses with marked separation of enlarged follicles. In the spaces free cells, some showing marked phagocytosis, were present.

Generally speaking, the tissue changes observed showed essentially these features in varying degrees. The more prolonged the exposure, the more marked the changes. Exposure to wet mud as contrasted with dry mud resulted in earlier and more marked changes but to no significant difference in the type of tissue reaction.

Notably absent was thrombosis of the vessels, vasoconstriction, or significant changes in the nerves. More prolonged exposure resulted in some edema of nerve tissues, to deposition of fibrin, and also to an increase in the number of micro-organisms, staphylococci and streptococci, noted.

Tissues subjected to heat, and tissues subjected to constriction showed in addition extravasation of red blood cells into the edematous tissues, and in some cases actual hemorrhage. The authors concluded that this was due to the damaged vessels giving way under the strain of additional trauma.

Brahdy[18] described the findings in tissues removed several months after the development of the lesions seen in ordinary frostbite in civil practise. These tissues showed atrophy of the skin, necrosis of bone, the presence of large amounts of granulation and fibrous tissue and thrombosis in the vessels.

Tissues taken many months after the development of the lesions from cases in our group of shipwrecked mariners were strikingly similar. The most striking feature was the presence of a large amount of fibrous tissue throughout the sections; inflammatory cells were still present but scar tissue was predominant. The blood vessels showed marked thickening with endarteritic changes of a productive nature narrowing the lumen. Even the marrow spaces of the bone showed a marked deposition of fibrous tissue and many of them were filled completely with it. Careful study revealed no changes in the nerves. It is obvious that the pathological changes in tissues removed from patients seen clinically represent the end results of a process similar to that recorded as occurring in experimental animals.

It will thus be seen that we can reconstruct in some measure at least, from the data available, the sequence of events in tissues damaged by cold. The essential feature of the reaction in the tissues is its inflammatory nature. All tissues affected respond in a similar fashion. From the beginning there is a notable tendency to deposit

fibrin and later an enormous amount of scar tissue is the result. Damaged vessels respond by inflammatory changes in the vessel walls and in the later sections we see the end result of this inflammation.

The animals utilized by Smith, Ritchie and Dawson recovered rapidly when removed from the cold chamber in which the experiments were conducted. Clinically, by far the greater number of cases seen by us in our group of shipwrecked mariners recovered without apparent permanent disability although there were, unfortunately, many exceptions to this rule. Thus the changes in the tissues are up to a certain point reversible. Where exposure is prolonged, tissue reaction is of such a degree that restoration to integrity is no longer possible and permanent tissue changes or loss of tissue results.

TREATMENT

Larrey[1] first recorded the harmful effects of the application of heat to tissues damaged by cold and noted the frequent onset of gangrene in tissues so treated. Smith, Ritchie and Dawson[10] have shown experimentally that rapid warming of the affected parts greatly aggravates the condition and this was confirmed by Lewis and Love.[15] Greene[20] has shown that if the tail of a mouse is frozen, the tissue loss is twice as great if the mouse is held before a warm fire. There is thus ample clinical and experimental evidence against the use of heat locally.

In first degree frostbite the affected extremities are, during the stage of reaction, hot to the touch and in second and third degree frostbite the areas above the level of complete, or dry, gangrene are also hot to the touch. Skin temperature readings on these parts are uniformly several degrees higher than those of the affected extremities. From the pathological data available it is obvious that we are dealing with an inflammatory reaction.

In an effort to control the blood supply to the affected limbs and thus to minimize tissue reaction Lake[13] suggested the use of vasoconstrictor drugs but was not impressed with the results. Lewis and Love[15] suggested the use of a tourniquet with the same object in view. It would seem from the work of Smith, Ritchie and Dawson that this latter might be productive of more harm than good.

The application of cold to frostbitten parts is traditional. Recently, it has been endorsed by Webster, Woolhouse and Johnston[27] and suggested by Greene.[30] On theoretical grounds there is ample justification for its use. Cooling would both decrease the blood

supply to the affected part and, by reducing the metabolic procesess in damaged tissues lessen the oxygen requirements and so result in a decreased demand.

Webster, Woolhouse and Johnston[27] have reported dramatic improvement in patients treated by refrigeration. They employed fans blowing a current of air, chilled by ice trays, over the damaged extremities.

Greene[30] has devised an ingenious cabinet with one compartment for the damaged extremities and a second for the refrigerant, solid carbon dioxide. The cabinet is provided with adequate controls for regulating the temperature of the therapeutic compartment. Greene had not had an opportunity of testing this device when the communication describing it was published. He suggested that its efficacy should be tested for a time by treating one limb only of a bilaterally affected limb and using the opposite limb as a control.

The majority of the patients in our series were not treated by refrigeration but the limbs were elevated and exposed to room temperature, covered only with sterile towels and in the majority of cases protected from infection by mild skin antiseptics or a dusting powder containing one of the sulfa drugs. In none of these patients was there any extension of existing gangrene and in none did gangrene occur if it were not present upon admission.

In a small group of cases occurring late in the series refrigeration by means of ice bags was employed. In bilateral cases ice bags were applied only to one limb, the other being left exposed at room temperature. We could see no appreciable difference resulting from the application of ice bags and the patients did not notice any improvement subjectively in the cooled limb nor were they always perceptibly co-operative in keeping their extremities in contact with the ice bags provided.

It must be emphasized that these findings are not regarded as conclusive for the series was small and some of them were aboard rescue ships several days before reaching the hospital for treatment, so that some of the tissue reaction might reasonably be supposed to have subsided. They do indicate, however, that unreserved acceptance should not be given to this method of treatment and that its cautious application under carefully controlled conditions may help to determine its true importance.

Because of the risk of additional trauma to the tissues massage should be avoided in the early treatment of frostbite. Greene[28] also

advises against the use of the Pavex boot in this stage of the disease. With this opinion there can be no disagreement.

Miscall[21] suggested the use of paravertebral sympathetic block and it has been employed by Penberthy.[33]

There is every evidence that in the stage of reaction, when there is increased heat in the tissues clinically, anything which might increase this reaction should be avoided. Its use in early cases would, therefore, seem to be positively contraindicated.

This led us to wonder if there might be some justification for its use later on when the primary inflammatory reaction had subsided. Here its use might reasonably be justified by the hope that it would hasten healing of tissues in proximity to areas of gangrene. We, therefore, decided to try the effect of spinal anesthesia on skin temperatures as measured by the thermocouple in cases of second degree frostbite. Several patients were treated in this manner. The results obtained in two such cases are shown in Table II.

One was a case of frostbite in a rescued seaman in whom immersion had been a factor, the other a young man suffering from second degree frostbite as a result of exposure for several days when he went astray while on a hunting expedition.

The result in each case was the same. There was no appreciable difference in skin temperatures following the administration of a spinal anesthetic. We, therefore, concluded that the use of sympathectomy would be of no value.

In second degree frostbite in which dry gangrene is present amputation should not be practised. The formation of an apparent line of demarcation is deceptive. Superficially, the area of gangrene is always much more extensive than is the gangrene in the deeper tissues. One patient in our series showed a line of demarcation in one foot extending to just below the malleoli on the plantar aspect of the foot and to the mid-metatarsal region on the dorsal aspect. Spontaneous separation was permitted. The final result was loss of the toes only and a few skin grafts over the heads of the metatarsals were all that was required to complete healing. This observation is not original. It has been strongly stressed by Rabut,[22] Greene[24] and Thompson;[26] yet in spite of their warnings many limbs have been needlessly sacrificed because of the existence of a traditional "line of demarcation." This type of gangrene presents no threat to the welfare of the patient and there is no justification for early amputation. It is my belief that there is no justification for surgical

TABLE II

T. M. age 18, Second degree frostbite
Room Temperature 70°F.; body 98°F. (oral)
Time before spinal—Extremities exposed 60 minutes at room temperature prior to beginning of readings

Time	Thermos Temp.	Volt. Read.		Extremity Temp.	
		L.	R.	L.	R.
0.10	28.5	−3.5	−3.25	32.	31.75
0.15	28.35	−3	−3	31.35	31.35
0.20	28.35	−3	−2.5	31.35	30.35
0.25	28.3	−2.75	−2.5	31.05	30.8
0.35		Spinal 100 mg. novocaine			
0.40	28.2	−0.75	−0.5	28.95	28.7
0.45	28.2	−1.0	−2.0	29.2	30.2
0.46	28.1	−2.25	−2.5	30.35	30.6
0.48	28.1	−2.25	−2.5	30.85	30.35
0.52	28.1	−2.75	−2.0	30.85	30.1
1.00	28.	−2.2	−1.7	30.2	29.7
1.05	28.	−1.7	−1.7	29.7	29.7
1.10	27.4	−2.7	−2.0	29.7	29.4
1.15	27.4	−3.0	−2.0	30.4	29.4

F. R. Y., Second degree frostbite
Room Temperature 70°F.; body 98°F. (oral)
Time before spinal—Extremities exposed 45 minutes at room temperature prior to beginning of readings

Time	Thermos Temp.	Volt. Read.		Extremity Temp.	
		R.	L.	R.	L.
10.35	26.3	−3.25	−3.25	29.55	29.55
10.40	26.3	−3.5	−3.25	29.8	29.8
10.45	26.3	−3.25	−3.25	29.55	29.55
10.50		Spinal 100 mg. novocaine.			
10.55	26.2	−3.25	−3.12	29.45	29.32
11.05	26.2	−3.25	−3.12	29.45	29.32
11.15	26.1	−3.25	−3.5	29.6	29.6
11.25	26	−4	−3.5	30.	29.5
11.40	27.4	−2.5	−3	29.5	30.5
11.45	27.4	−2.5	−2	29.9	29.4
11.50	27.4	−2.5	−2	29.9	29.4
12.00	27.3	−2.5	−2	29.9	29.4

interference whatever beyond the removal or trimming of necrotic bone when spontaneous separation has occurred and the judicious use of skin grafts where necessary.

In third degree frostbite wet gangrene is present extending above the ankle and in severe cases above the knee. These cases are gravely ill and the limb must be sacrificed to save life. They differ from first and second degree cases in one important aspect. They appear extremely toxic and have a high temperature which does not subside when treatment is instituted. Although patients with first and second degree frostbite show rapid improvement in their general condition, these patients deteriorate from day to day. The real nature of their condition soon becomes apparent. The larger tissue masses of the leg have been damaged beyond recovery and a "wet" or incomplete gangrene is present. Saprophytic infection contributes to the toxicity and is present even before any break in the skin is manifest.

While these cases may be difficult to recognize, when first seen the presence of a high fever is significant in the absence of intercurrent infection. They are soon recognized, however, and as soon as the patient's condition permits amputation must be performed. If the gangrene is of the wet type, prosthesis should not be taken into account at this stage but guillotine amputation is not necessary and the cutting of flaps is permissible if feasible. In those cases in our series in which flaps were cut and closure practised the patients did uniformly well. This is in keeping with the observation that we are dealing here, not with infection, but with incomplete gangrene.

In those cases of frostbite in which dry gangrene extends into the denser tissues of the leg there might be some justification for classification of these cases as fourth degree frostbite. Since loss of limb would be the result in these patients, we believe that for statistical purposes they can best be classified as third degree. In such cases amputation could be performed leisurely and prosthesis would be the guiding factor as to site of amputation.

CONCLUSIONS

1. All lesions resulting from exposure to cold are essentially similar. The term "frostbite" is adequate to describe them regardless of the circumstances under which they occur.

2. A clinical classification of frostbite depending upon degree of severity is proposed.

3. The use of heat is harmful; the use of refrigeration may be of value in dealing with these lesions but requires further study.

4. The use of sympathectomy is contraindicated in early treatment and cannot be shown to be of value in late treatment.

5. When dry gangrene is present, the "line of demarcation" is deceptive; avoid amputation; allow spontaneous separation.

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AN ADDITIONAL REPORT ON SOME OF THE USES OF CUTIS GRAFT MATERIAL IN REPARATIVE SURGERY*

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IN 1939, the report of Uihlein[1] concerning Rehn's[2] work with cutis (derma) in surgical repair procedures was brought to my attention and I decided to make use of the method. Our first operative use of cutis was in July, 1940, at which time Dr. Bankhead Banks and I repaired a very large epigastric hernia. A very satisfactory result ensued. Since that time we have gradually found increasing indications for the use of the method.

At the December, 1941, meeting of the Southern Surgical Association, I presented a review of the literature on the subject and reported the successful use of the method in fourteen cases. In the cases reported at that time were six large incisional hernias, five direct inguinal hernias in which the structures were defective, one fracture of the patella, one on-lay bone graft for non-union, one suspension of the cervix in a case of prolapse of the uterus—all with primary healing and apparent good results.

At the Boston meeting of The American Association for the Surgery of Trauma, June 4, 1942, a further report of cases in which cutis grafts had been used was made, bringing the total number of cases to thirty-seven.

At the Chicago meeting of the previously mentioned Association, June 9, 1944, a total of eighty-six cases in which cutis had been used was reported.

The use of the cutis graft has been rather generally recognized by the plastic surgeons and more especially by Peer[3] and Paddock, Smith,[4] Ivy[5] and others. Recently, a report of its successful use in the repair of an abdominal incisional hernia has been made by Swenson[6] and Harkins, of the Henry Ford Hospital.

Indications. Cutis transplants may be used to take the place of fascia lata whenever and wherever indicated and to give more satisfactory results, e.g., to repair or reinforce defects in aponeurotic

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FIG. 1. Ankylosis of jaw before operation.

FIG. 2. Ankylosis of jaw after cutis graft repair.

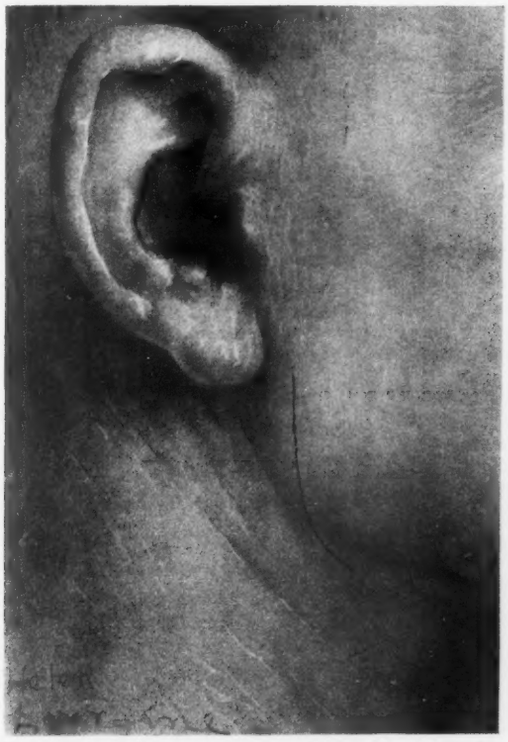

FIG. 3. Ankylosis of jaw; outline of incision for operation.

FIG. 4. Ankylosis of jaw; operation showing double thickness cutis graft in place.

FIG. 5. Large incisional abdominal hernia previous to operation.

FIG. 6. Large incisional abdominal hernia after cutis graft repair.

structures, to replace destroyed dura, to reinforce or replace external and internal ligaments of the knee or other joints, to restore the lining of joints, for interposition between fractured long bones for

FIG. 7. Closure of subcutaneous fat when cutis graft is used.

the prevention of synostosis, to reinforce the walls of aneurysms in case of impending rupture,[7] to restore normal contour to the nose, lips and face,[8,9] in the stage ligation of blood vessels, for autoplastic sutures, and as a support for the bowel in colostomy. Cutis, along with a layer of fat and aponeurotic tissue, has been used by Berson[10] for the filling out of defects of body contour such as after the resection of all or a portion of the breast, the reinforcement of the aponeurosis of abdominal muscles that have lost their tone from local paralysis such as at times may follow poliomyelitis,[11] to correct diastasis of the buccinator muscle developing in glass blowers and at times in musicians who blow horns.

Technic. The present technic is as follows: The skin is prepared with iodine followed by alcohol. A thin layer of skin is usually removed with a skin graft knife or, if only a strip of cutis is to be

used for suture or ligature purposes, the epidermis can be readily removed with a Durham Duplex safety razor blade. The antero-external surface of the thigh is usually the favorite donor site. If

A B

FIG. 8. A, multiple fracture of patella before operation, B, fracture of patella after cutis graft repair.

the raw area left is not too wide, the skin edges can be readily approximated; or if a large graft has been taken, the epidermal layer can be used as a skin graft to cover the raw area. The graft is sutured into position under firm tension with No. 30 or No. 40 interrupted cotton thread sutures spaced rather close together. The wound is irrigated with normal saline solution. A moderate amount of sulfanilamide is placed in the wound, at times a little crystalline sulfathiazole also. The subcutaneous fat is accurately sutured over and down to the center of the implanted dermal graft with No. 70, 80, or 100 interrupted cotton thread sutures, the needle bite picking up a portion of the center of the graft with each suture. In case the patient is very obese a second layer of sutures is placed in the fat. All dead space is carefully eliminated, no drains are used, a moderate pressure dressing of mechanic's waste is applied over the wound and is kept in place for about ten days. These patients are gotten out of bed daily beginning on the day following operation.

CASE REPORTS

CASE I. R. B., a white male, age twenty, was admitted to the hospital July 13, 1942, with a compound depressed fracture of the left parietal region. There was a deep laceration of the left parietal region. *X*-ray examination indicated that a portion of the depressed bone had been driven into the brain for the depth of about one inch.

Operation was performed soon after admission, by the surgical resident, Dr. Victor Skaff. The traumatic incision was débrided and elongated. The depressed areas of bone were removed. A considerable amount of brain tissue escaped. The lacerated meningeal artery bled freely and was controlled by electrocoagulation. The area from which the bone was removed was about one and three-fourths inches in diameter. Since a considerable portion of the dura had been so badly lacerated that it could not be satisfactorily sutured on, a cutis graft was taken from the left thigh and sutured over the damaged area of the dura. When in place the graft covered most of the opening in the skull. The temporalis muscle was sutured over the graft and the scalp closed with interrupted sutures in the usual manner. The patient had an uneventful convalescence and was discharged from the hospital July 24th, apparently in excellent general condition. When seen about six weeks later the area over the bony defect that had been covered by the graft was quite firm to the touch. It was apparent that the cutis graft had in considerable measure formed a protective covering over the area of brain that had been exposed.

CASE II. S. D., a colored male, age twenty-seven, was admitted to the hospital October 30, 1942, with a history of an injury to the left shoulder received in a mine accident which resulted in inability to move the shoulder in a satisfactory manner. A diagnosis of dislocation of the acromial end of the left clavicle was made.

Under ether anesthesia operation was performed November 11th, by Dr. H. A. Swart and myself. The Bunnell technic was used except that a strip of cutis was substituted for fascia lata. Although this patient was apparently in vigorous health, his heart stopped beating and he died in the operating room just after completion of the operation. Autopsy was not obtained.

CASE III. J. H., a seven year old colored female, was admitted to the hospital on June 22, 1942, with total ankylosis of the jaw, right side involvement. The upper and lower teeth were firmly fixed in rigid position with a space of about one-eighth inch between. She was unable to chew her food and was forced to subsist mainly on liquids.

At operation July 7th, the ramus of the right jaw was subperiosteally divided about midline. This procedure is readily accomplished with a slotting burr. A folded strip of cutis was implanted between the bony ends.

Following this operation the child almost immediately enjoyed full use of her jaws to the extent that she was able to open her mouth and to protrude her tongue readily. A letter from her mother on February 1, 1944, was to the effect that the patient had good use of her jaws and has had no trouble in chewing her food or in opening her mouth since her discharge from the hospital.

CASE IV. R. L., a white male, age thirty-two, was admitted to the hospital on January 19, 1943, complaining of painful herniation of buccinator muscle, right side, incidental to his occupation as glass blower.

At operation on January 20, a nearly vertical incision corresponding to the normal lines in the face, was made. The skin over the area of the diastasis was separated from the underlying structures so as to expose the principal surrounding muscular aponeuroses. A cutis graft was sutured into position over the principal area of the diastasis. The patient has been seen on two occasions since his discharge from the hospital. The cheek is considerably thickened but the pain has entirely disappeared.

CASE V. E. J., a white male, age twenty-nine, was admitted to the hospital on September 29, 1943, with a comminuted fracture of the right patella.

At operation on October 11th, a strip of cutis from the right thigh was passed through a circular tunnel made in the aponeurotic structures immediately surrounding the patella. On tightening this strip of cutis tissue it was noted that the fragments of patella were rather well approximated. The free ends of the cutis strip were overlapped and firmly sewed together with interrupted cotton thread sutures. A plaster cast was applied to thigh and leg. A window was cut in the cast over the patellar region. The wound healed by primary intention. When the cast was removed on November 26th, there was considerable motion in the knee. The patient has been checked on since and the knee motion has been found to be gradually approaching normal.

Our series of eighty-six cases to date comprises the following conditions in which cutis has been used: five epigastric hernias; nineteen abdominal incisional hernias (in one of these cases the patient did not take the anesthetic well and died shortly after completion of the operation, apparently from respiratory failure); one umbilical hernia; twenty-three direct and indirect inguinal hernias; one case of ankylosis of the jaw; one case of diastasis of the buccinator muscle (glass blower's hernia); one case of extreme diastasis of the rectus muscles; in fourteen cases to suspend the uterine cervix for the relief of prolapse; in one case to suspend the urethra for the relief of urinary incontinence; six cases of wobbling knee; three cases of fracture of the patella; one case of fracture of the ulna; in

one case for stage ligation of the common carotid artery; one case for partial occlusion of the femoral artery for the control of a popliteal aneurysm; in two cases for replacement of torn dura; to support the bowel in four cases of sigmoid colostomy; one case of luxation of the acromial end of the clavicle; and one case of marked bulging of the lower abdominal aponeurosis.

Complications. Complications have been few. In my personal series of fifty-seven cases there has been one hematoma, one serum pocket, three superficial infections, and one death, cause undetermined. In none of my cases has there been loss of the graft. One of our associates has had one death following operation, probably from shock and anesthesia in case of a large incarcerated hernia. This patient was greatly overweight and a very poor risk. Another one of our associates has had two rather extensive infections. In one of these cases the graft was lost.

SUMMARY

After this clinical experience with the uses of cutis (derma) in repair surgery, I am convinced that cutis is the most useful autoplastic repair material that we have; that it is superior in strength to fascia lata and of much easier availability; that success in its use can be expected in a large percentage of cases; and that it is of especial value in the surgical repair of many types of traumatic injury.

The following doctors have given permission to report their individual cases in which cutis grafts have been used: Dr. Bankhead Banks, twelve inguinal hernias; Dr. Hugh Bailey, one inguinal hernia; Dr. Randolph Anderson, five cases of wobbling knee; Dr. Howard Swart, one case of wobbling knee; Dr. A. A. Wilson, one dural repair; Dr. Victor Skaff, one dural repair, one suspension of the uterine cervix, two inguinal hernias; Dr. George Miyakawa, one fracture of the patella; Dr. Josef Haber, one abdominal incisional hernia, one suspension of the uterine cervix, one bilateral inguinal hernia with bilateral use of cutis and one inguinal hernia.

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SHOULD NON-TRAUMATIC AND NON-INFLAMMATORY CHANGES IN THE SPINE BE COMPENSABLE?

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THE present tendency of Compensation Boards to award total permanent disability to older workmen who claim an aggravation of ancient pre-existing hypertrophic changes about the spine and spinal joints presents one of the commonest abuses of our legal system. Surgeons specializing in the treatment of injury and those who by necessity must explain what is traumatic and why to a lay jury or Compensation Board are at a tremendous disadvantage.

There are two definite reasons for the abuses arising out of this type of claim: The first is the result of a confusion of terminology inherent in the discussion of degenerative and inflammatory conditions. This is probably the result of the persistence of a concept in the minds of English speaking people based on the principles enunciated by John Hunter, who described various types of reaction to trauma as inflammatory, so that there is no strict differentiation in pathology texts between the invasion of tissues by infecting organisms and tissue changes resulting from mechanical trauma. When one says "bursitis" or "arthritis" such terms make no commitment as to whether infection or mechanical damage to the synovial lining, the blood supply or other soft tissues is being described. Unfortunately, we have no simple terminology which differentiates and will develop none until our concepts are more definitive.

The second arises out of the very nature of our present legal procedures. Nothing fits in so well with our system of cross examination as an attack by the examiner on a subject concerning which the terminology is confused. The whole difficulty devolves upon the inability of the surgeon of trauma clearly to explain what pathological conditions are traumatic or influenced by trauma and what is perhaps degenerative or hypertrophic, reconstructive or functional and wholly unaffected by trauma.

The purpose of this paper is to offer some brief, and we hope provocative, suggestions that may lead to the simplification both

of our concepts of the relation of trauma to certain non-inflammatory diseases of joints and our terminology in describing these conditions.

For the most part, this discussion will be confined to affections of the spine which exemplify the types of joint conditions in question.

In discussing the relation of trauma to these various entities this word "trauma" is employed in a special and definitive sense to mean a sudden mechanical external violence or a sudden single, unusual, unexpected occurrence and not to include the repeated and ubiquitous habitual stresses and strains or "microtraumatica" to which the spine of man is subjected in his daily work. In other words, we wish to distinguish the main disabilities of the back which may be of traumatic origin and those which are definitely not traumatic in origin and are unaffected by accident.

Recent development in roentgenological technic as a result of the efforts of Dittmar,[1] Ghormley,[2] Jordan,[3] Lange[4] and others make a diagnostic study of the normal and pathological aspects of the spine feasible; whereas, ten years ago the more intimate details of changes in the small articulations of the spine and their relation to changes in the bodies of the vertebrae were not possible.

It is most unfortunate for our purposes that the sub-committee on nomenclature of the British Committee on Chronic Rheumatic Diseases, appointed by the Royal College of Surgeons, in 1935 adopted a classification quite similar to the grouping of chronic affections of the joints advocated by the American Rheumatic Association. These two classifications with various modifications have now become generally accepted in the medical literature of the English speaking peoples. Such affections are divided into two great groups: (1) Rheumatoid arthritis, atrophic arthritis, infective arthritis, etc., (2) osteoarthritis, hypertrophic, degenerative arthritis, etc.

It is in the second division or group that we are vitally interested. It may seem presumptuous to attempt to offer a new classification in a field already confused by various terminology based on clinical, etiological, pathological or roentgenological data, or all of these. I believe that men interested in the estimation of the rôle played by trauma must of necessity adopt an entirely new nomenclature. They must definitely disregard any such prevalent terms as osteo-arthritis, degenerative arthritis or hypertrophic arthritis in the description of diseases which are not inflammatory in nature.

One escape from our dilemma was suggested by Dr. A. W. George and Dr. R. D. Leonard, of Boston, who, in 1928, published a monograph "The Vertebrae,"[5] and stated, in substance, that they were discarding the terms hypertrophic and osteoarthritis entirely since they found that the various patterns of calcium salt deposition about the margins of joints of the vertebral arches as well as the hooks and spurs extending out from the attachments of long and short spinal ligaments are in nature entirely unlike arthritic deposits in their roentgenological appearance and anatomy.

Sometimes these calcifications have some resemblance to that which develops in the walls of arteries with the passage of time and the operation of various other non-traumatic influences. Certainly no one has contended that arteriosclerosis with subsequent calcification is traumatic.

George[6] finds that the pattern of these calcifications does not change nor their development increase or become accelerated after a trauma; therefore, he employs the term "hypertrophic changes" in his description. He says that in the abstracts of his monograph appearing in the literature of various countries of the world this change of nomenclature has been accepted. He also advises me in 1941 that Dr. Marius Smith-Petersen, of the Massachusetts General Hospital, Chief of the Orthopedic Service there, will not allow his students to employ the term "hypertrophic arthritis," when speaking of the vertebrae.

I am not sure that the term "degenerative" should be applied to calcifications about the spine, since while "degenerative" may be applied to some of the changes in the intimate structure of ligaments where they occur, the "buttressing" effect and ultimate substantial "bridging" tendency of these depositions may strengthen the spine locally or in general. Hence, viewing the whole spine as a structural unit they may be functional and not degenerative.

Therefore, I believe we should employ, and scrupulously adhere to, the nomenclature accepted in all continental medical literature. This, I believe, was first proposed by Frederick Mueller of Munich, at an International Congress on Chronic Rheumatic Affections in London in 1913[7] to emphasize the non-inflammatory nature of hypertrophic and osteoarthritis. He suggested the substitution of the term "arthrosis." He employed "sponkylosis" in preference to spondylitis for all non-inflammatory or degenerative affections of the vertebral bodies themselves.

Since spondylosis, a chronic change of the edges of the bodies of the vertebrae, with development of ankylosing and projecting hooks, spurs and osteophytes, is the commonest condition seen in routine *x*-rays of the spinal column, and commonly occurs in spines entirely unaffected by any changes about the small joints which may be painful, Mueller described this as a separate entity. He also discussed changes about the small joints of the arches, ordinarily not painful and unaffected by trauma. These he terms arthrosis.

SPONDYLOSIS

This is the commonest affection to which the vertebral column of man is subject. Calcification probably affects no other part of the skeleton so frequently as the spine. The changes do not constitute a disease *sui generis*. In some degree they may represent a physiological response to repeated mechanical stress, a kinetic or "formative" stimulation.

The age at which calcification appears in the costal cartilages, arteries, spine, etc., may be determined in part by hereditary tendencies. The term "spondylosis deformans" in a strict sense can be applied only when permanent changes in a series of vertebral bodies and ligaments are associated with lasting alteration of posture, usually with a kyphotic curve.

The occurrence of spondylosis increases with each decade past middle life so that Garvin[8] in 2,000 roentgenograms of the spine, made at the Mayo Clinic, chiefly for the study of the urinary tract, found that it was present in the lumbar region in 67 per cent of men and 40 per cent of women at fifty years of age, and that 74 per cent of these men and 61 per cent of the women had no complaints referable to the back. He, therefore, termed these changes "incidental" and said that the improbability that a single accident was responsible in any way for the affection was quite obvious.

In the examination of 625 lumbar spines, Willis[9] found that no lipping existed in any of these at the age of thirty-five. At the age of forty-five, however, 83 per cent of those of heavy body type and 10 per cent of those of slender type showed spondylosis. At fifty years all the heavy type and at fifty-five all of the average type and at sixty years all of the slender type presented these changes. This shows the ubiquitous occurrence of this affection past middle age.

Searches for a possibility of an infective element in the etiology of spondylosis has been extensive and unsuccessful. Cecil, Nicolls

and Stainsby,[10] in 1929, Nye and Waxelbaum,[11] in 1930, and Gray and Gowen,[12] in 1931, who have extensively studied the bacteria factor in chronic arthritis are unanimous in finding entirely negative results in both arthrosis and in spondylosis. Various immunological tests, including streptococcic agglutinations and antistreptolysin test, have been totally unproductive of any positive results. Buckley[13] and others in England have run long series of sedimentation rates on these cases without being able to find any relation between abnormally rapid sedimentation and the existence of spondylosis. I have run 200 sedimentations by the Cutler method without one positive result, except such as were easily explainable by very definite sources of infection entirely independent of the spondylosis.

Investigation of the occurrence and character of the osteophytic growth at the edges of the vertebrae has been made in an exhaustive study by Schmorl,[14] who made an autopsy examination on 10,000 spines; and in a large series of spines by Shore,[15] of Cambridge University. Their results are interesting.

ANATOMY OF OSTEOPHYTES

The osteophytic changes which commonly arise as spicules or as fringes are lipping of the vertebral bodies on their anterior and lateral aspects. In Shore's series no osteophyte was found on the posterior edge abutting the spinal canal or the intervertebral foramen. Beadle[16] makes the same observation after a review of Schmorl's series. Osteophytes usually bear longitudinal striations corresponding to ridges in the ends of the bodies of the vertebrae best seen when they are of moderate size. Osteophytic production may be extensive enough to span an intervertebral space. An incomplete bridge should not be mistaken for fracture of an osteophyte, although such a condition is not painful or of clinical importance. Almost never is osteophytic production limited to a single unit of the vertebral column. I am not referring to the regular callus depositions after a vertebral fracture, which have distinctive morphology ordinarily distinguishing them quite easily from actual osteophytic lipping. Since the work of Schmorl many writers have mentioned the collapse of an intervertebral disc as the important etiological element in the development of marginal lipping of the bodies; but if you will review any series of your own, as I have found in reviewing my routine *x*-rays of the back, even extensive osteophytic production

is ordinarily not associated with any diminution of the intervertebral spaces.

That spondylosis is not entirely dependent upon weight-bearing is examplified in the study of the distribution of the osteophytes at different levels in Shore's series. In summary, his study shows that the liability of vertebrae to marginal changes increases as one goes from above downward with three well defined outcrops of spurs, one in the cervical region, another a thoracic outcrop, and finally a lumbar outcrop which is highest in the mid-lumbar region and falls to a minimum at the lumbosacral junction, where if weight-bearing were the definitive etiological factor the greatest pathological process would inevitably be found.

PATHOLOGY OF SPONDYLOSIS

The entire vertebral column is enveloped in a continuous sheath of fibrous tissue, the perivertebral sheath described by Poirier and Charpy,[17] composed of a deep layer of short ligaments extending from one vertebral border to the next and attaching at the outer epiphyseal groove, which is the exact region where the osteophytic growth and lipping begins. In addition to this deeper sheath, there is a more superficial and powerfully developed layer specialized into the common anterior and common posterior ligaments. The powerful common anterior ligament is attached to each vertebral body at the outer edge of the epiphysis, superficial to the area where the osteophytes are produced. When these form they push the anterior common ligament forward, not invading it but are enveloped in the deep short and more delicate ligaments which attach each vertebral body to the one above or below. The importance of this distinction lies in the fact that the intervertebral discs and the deeper intervertebral ligament layers contain few if any pain or sensory nerve endings. Possibly the anterior ligament has some distribution of pain endings.

Since the osteophytes arise in the deeper and non-innervated ligaments and not in the common ligament, they are certainly not pain producing, as clinical evidence substantiates their common occurrence in non-painful backs.

In this description I am speaking of the innervation about the vertebral bodies in distinction from the innervation of the small joints of the arches of the vertebrae these are supplied like other

joints by synovial pain endings unquestionably affected by diseases producing pain.

FRACTURE OF THE SPINE AND SPONDYLOSIS

Through the research of Gaugele,[18] Haumann[19] and Hellner[20] it has been definitely shown that generalized spondylosis does not result from a fracture of the spine. Subsequent observations of Max Lange,[21] of Munich, and Schmorl's investigations of a large series of spines corroborates this. I believe there has been a common tendency loosely to assume that after a compression fracture of the spine the changes produced about the affected vertebra corresponded to spondylosis. A careful roentgenological study of reconstructive changes about any compression fracture will confirm my own observations and those of the men cited above that callus formation is bizarre in character and conformation, and is not identical or even easily confused with the marginal osteophytes of spondylosis, which I have been describing.

DOES SPONDYLOSIS PROCEED MORE RAPIDLY AFTER VERTEBRAL FRACTURES?

There is no evidence that spondylosis occurs after a fracture of one or several vertebral bodies or that it proceeds more rapidly after a vertebra has been crushed.

ARTHROSIS AND PAIN

Recurrent and persistent pain in the spine is not the result of chronic changes about the vertebral bodies but may result from structural changes in the small articulations. These articulations of the arches are the only true joints of the spine. Each articular process bears a facet which is covered with cartilage. The joints between these are provided with synovial cavities and a varying amount of synovia. The anterior parts of each of these synovial capsules forms a posterior margin of the intervertebral foramen to which the corresponding spinal nerves pass.

With the exception of the articulations of the cervical spine the development of the oblique view for the visualization of the small joints is a determining factor in our present ability to study pathological changes in these joints which prior to this time were very poorly understood.

The commonest affection of these joints is arthrotic in nature which is observed roentgenologically as: (1) Changes in consistency or density of the borders and bases of the articular facets, which finally progress due to degeneration and attrition of the joint cartilages allowing the unprotected bone on either joint surface to come in contact. Such a distorted joint may be painful. If such a joint is distorted enough to be painful, the pathological process can be very definitely demonstrated by *x*-rays.

The tendency to marginal lipping is not nearly so marked and occurs later in the course of these joint affections than in spondylosis. Strangely enough changes around the bodies even of advanced degree are not likely to be associated with any change around the spinal joints and conversely even advanced arthrosis in the latter position is commonly not associated by any marked degree of spondylosis, so that these two diseases are actually separate clinical entities not often found associated with each other.

Arthrosis is likely to occur at an earlier age than spondylosis. The most conspicuous calcifications about both the bodies and the joints of the spine are found in connection with static deformities, e.g., the dorsal kyphosis of later life, or that resulting from Scheuermann's disease. Scoliosis also have its quota of subsequent or secondary arthrosis. Only the advanced degrees of this disease present actual joint surface erosion and persistent pain due to this cause.

SACRALIZATION AND ARTHROSIS

In 748 skeletons Willis[22] found that 7 per cent presented a transverse process of the last lumbar vertebra which impinged upon, articulated with or was fused into the lateral mass of the sacrum. At first there was a considerable difference of opinion as to whether and how pain was produced by this sacralization. Bertolotti,[23] Leri[24] and Putti[25] thought that painful conditions occurring in this anomaly was caused by nerve pressure or venous stasis. Later roentgenological studies and directions silenced these contentions. Menard[26] operated upon thirty of these and found no compressions. We now know that like arthrosis of the spine a nearthrosis between a transverse process and the sacrum or ilium is or can be painful when: (1) Physical examination indicates objective evidence of local, painful disease;[27] (2) and when the *x*-ray shows a false joint which has a joint space obliterated, with little vestige of cartilage remaining and the joint margins thickened or distorted.

Quite similar criteria distinguish painless spondylolisthesis from a painful condition in this anomaly. It is well known that advanced cases of spondylolisthesis occur in which there is no pain and the finding is only incidentally picked up in connection with *x*-rays taken for other purposes than painful backs. Advanced arthrotic changes in the lumbosacral joints or in a nearthrosis formed in association with spondylolisthesia can unquestionably be painful.

I have seen many cases of fairly well developed spondylolisthesis in men who were working and who from time to time sprained their backs but recovered entirely. The question of whether spondylolisthesis demands a surgical intervention depends in a large part upon how much arthrosis has developed at the lumbosacral joints and whether it is of a painful or painless type.

CONCLUSION

1. The painless nature of chronic back conditions described roentgenologically by such terms as "hypertrophic changes," sponkylosis and arthrosis can be determined with certainty by systematic physical and roentgenological examinations.

2. It seems in order to suggest that a committee from the American Association determine what terminology would best enable us to avoid the embarrassment of describing the non-disabling changes of advancing age in terms suggesting permanent or total disability.

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CURRENT EXPERIENCES IN PLASTIC SURGERY AMONG NAVAL PERSONNEL*

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THE present military conflict has given rise to a rather wide group of traumatic lesions, which in time are brought to the attention of the plastic surgeon. Space will not permit a discussion of all of the interesting problems that are a constant challenge to the operator's skill and imagination. Since the injuries caused by burns are extensive and varied, I have chosen to limit this paper to a discussion of some of our experiences with this group of cases.

Burn injuries as they have been seen in our plastic service may be divided into four groups: (1) systemic damage; (2) repair of granulating cutaneous defects; (3) late correction of healed scar contractures and (4) unusual complications.

SYSTEMIC DAMAGE

We have seen many casualties who had been extensively burned and who for various reasons did not arrive at the mainland until several weeks after their original injuries. Usually the story recounted was that the patient was too ill to warrant earlier transfer and when he could be moved, rapid transportation facilities over several thousand miles of enemy infested land and sea was often difficult. Consequently, when these men would be admitted, two or three months would have elapsed following the initial burn.

On admission, a typical patient was found to be very emaciated and septic. True enough, large amounts of plasma and blood transfusions had been given, but open infected granulating defects amounting in many cases to several square feet of surface area, permitted the very rapid escape through them, of large quantities of the patient's serum. The blood studies showed anemia and a low serum protein level. Owing to the pain associated with a lesion of this type large amounts of opiates had been given. This was of course a necessity, but the prolonged use of this type of drug lead

* The opinions and views set forth in this article are those of the writer and are not to be considered as reflecting the policies of the Navy Department.

to a few minor cases of addiction. While the problem was readily corrected after skin grafting had been started, it did contribute to the patient's loss of weight through lack of appetite. A septic fever was a common occurrence until the patient had been properly prepared and skin grafting operations instituted.

With the foregoing picture it is quite obvious that we were dealing with a poorly nourished, anemic, septic, and emaciated group of patients. They were very sick individuals that needed much preoperative preparation before any surgery could be undertaken.

Varying amounts of serum and blood were given by transfusion. It was difficult to specify any adequate dosage, but it seemed quite evident that we often erred by giving inadequate quantities. Generally speaking, however, we attempted to give enough blood plasma to maintain a normal serum protein level. Blood was given in quantities sufficient to keep the hemoglobin reading up to 80 per cent and the erythrocyte count to 4,000,000 or more.

Since the majority of our patients had suffered serious and extensive extremity burns, adequate recipient veins were difficult to find. Consequently, we found it necessary frequently to use the jugular veins and to utilize the procedure of sternal infusions. This latter technic[1] is very simple and we believe from our rather extensive experience, that it should be utilized much more frequently.

The granulating defects themselves were prepared by a combination of treatments. The patient was given daily tub baths insofar as his physical condition would permit. This aided markedly in the loosening and floating off of crusts, pus, and other débris. The actual solution in which the patient soaked as a rule, did not seem to make a great deal of difference. Those who were bathed in plain warm water apparently progressed as well as those who were placed in physiologic saline or other solution. In other words, the benefit derived from tubbing seemed to be due chiefly to the physical effects produced by the solution into which the patient was placed.

All of the granulating defects were badly contaminated with Bacillus pyocyaneous infections as well as many other mixed organisms. The oral administration of sulfonamides gave no apparent benefit in our group. Their local application was of questionable value and in some instances gave one the impression that the local use produced excessive fibrous tissue reaction that manifested itself by undue contracture formation beneath the skin grafts. Several patients were given large doses of penicillin. This drug has

a very beneficial effect upon the mixed group of contaminating organisms, thereby making apparent a diminution of purulent discharge. It also aided the patient's general welfare by producing an increased appetite. However, we failed to note any effect whatsoever in controlling the Bacillus pyocyaneus infection in any case.

Following the tub bath, the granulating defect is covered first with sterile fine mesh gauze* and then a moist sterile gauze roll applied under moderate pressure. Sufficient catheters or Carrel tubes are incorporated into the dressing so that the mass may be kept moist by frequent irrigations through the tubes. The moisture is maintained further by keeping the dressing enclosed in wax paper, which in turn is covered with a large abdominal pad and secured with an Ace bandage. We have employed various solutions with which to keep the dressing moist. In our hands the use of a weak acetic acid solution did not seem to control pyocyaneus infection any better than saturated boric acid solution. However, the boric acid mixture appears to give cleaner wounds than when physiologic saline is used. Apparently the mild acidity of the boric acid exerts some benefit over saline. A few days of this type of treatment usually will give a clean granulating defect that will receive a skin graft. Incidentally, we have no hesitancy in skin grafting granulating defects that are contaminated with pyocyaneus providing the granulations themselves have a healthy appearance. The grafts will grow to almost a complete "take," and once the defect is covered with growing skin, the pyocyaneus problem is simultaneously corrected. Thus, in answer to many queries as to how we control the pyocyaneus, the answer usually given is to "cover the defect promptly with a properly selected type of skin graft!"

In addition to the local preparation, one should also give the patient a high caloric, high protein, and high vitamin diet. Additional vitamins are given by mouth. If the patient is at all able, we like to take him out of doors in a wheel chair where he will obtain additional stimulus from the warm sunshine.

REPAIR OF GRANULATING DEFECTS

Much has been written and said about skin grafts and the technical procedures involved in procuring them. For a long time I have advocated using "a properly selected type" of skin graft. This phrase implies that a certain amount of thought, experience, and

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consideration is being given to any problem necessitating a skin graft. In brief, we have long since concluded that the operator should attempt to utilize the simplest possible type of graft to fit the need of the particular problem at hand.

In covering extensive granulating defects such as we see following third degree burns, we have found that thin split-thickness grafts, cut in large segments, will give the most ideal results as measured in percentage of good "takes" and functional results. Furthermore, when donor sites are at a premium, as has been our experience many times, the donor area may be used repeatedly. The so-called "pinch" and "flagstone" grafts have not been used on our service except in a few isolated instances when adequate donor areas could not be found from which to take large sheets of skin. Moreover, it has been our experience that large grafts "take" better than small pieces. But most important, an area covered with pinch or flagstone grafts leaves a very poor covering, both cosmetically and functionally. Because of the large amount of scarring that develops between the grafted areas it is often necessary to remove these coverings at a late date and replace the defect with a large single graft.

The method of cutting the large split-thickness grafts may be left to the individual operator's skill and preference. We use both the Padgett dermatome and the Blair-Brown suction box and razor technic with about equal uniformity of results. The free hand method is simple and more rapid when good extremity donor sites are available. However, when one must take the graft from a poorly nourished scaphoid abdomen or from a moving chest whose skin is sunken between the individual ribs, the Padgett dermatome is far more efficient. Whichever method is chosen, we prefer to cut the graft relatively thin, i.e., about one-third total skin thickness. While this thin graft may not give optimum functional results around kinetic areas such as the hands and fingers, it has a good certainty of "take" and will serve to convert the open draining lesion into a closed wound. When necessary, this covering can be looked upon as temporary and may be replaced at a later date in the presence of a clean surgical field and when all other conditions are sufficiently ideal to insure a complete "take" of a more complicated skin grafting procedure.

It has been very gratifying to note the rapid improvement that these patients make when their open wounds are progressively covered with growing skin grafts. The loss of serum protein is

stopped, the anemias disappear, temperatures become normal, the patient gains weight, and in all respects rapidly becomes a human being again.

We have not used skin from other individuals. In light of our present knowledge, these isografts will grow only for a short period of time. Thus far we have had no occasion to resort to their use.

We have tried various original and modified applications of the coagulum contact[2,3] technic but in our hands, we have not had any greater success than with the well standardized procedures. Furthermore, we have lost surface area in attempting to follow the Sano plan because of the contraction of the graft by virtue of its own elasticity. Moreover, we have noted repeatedly that when split-thickness grafts are applied a natural coagulum develops rapidly between the raw surface of the graft and the underlying granulating bed. In fact, we have often observed with amazement, the speed with which this natural physiological reaction occurs.

HEALED CONTRACTURES

After the granulating surfaces have been well healed and adequate physiotherapy has been given, during which period the patients have been encouraged to be up and about, go out on liberty and, in general, live a normal existence, certain late corrections may be indicated. The thin graft around a joint may not give sufficient elasticity to permit full range of motion. In addition, some lesions come in to us that have been permitted to heal by secondary intention. Either instance not infrequently gives rise to a contracture of variable degree about the joint that will need secondary revision. These, however, can be corrected quite ideally as an elective procedure and in the presence of a clean surgical field. This condition in a now otherwise healthy patient has produced excellent "takes" of our grafts when fundamental technical principles have been observed. In correcting these late deformities, we still adhere to the principle of utilizing simple methods whenever applicable. In the correction of dorsal contractures of the hands,[4] contractures of the elbow, axilla, popliteal area, and the neck,[5] we have found that the use of thick split-thickness grafts gives excellent functional results when a good normal subcutaneous fat pad is present upon which to place the transplant. However, it is believed that in replacing surface defects on the flexor surface of the hand and fingers, the more complicated full-thickness skin graft will give better elasticity and a

better weight-bearing surface. This latter fact makes the additional effort involved of definite value when one considers the need of maximum function on the individual's palmar surface.

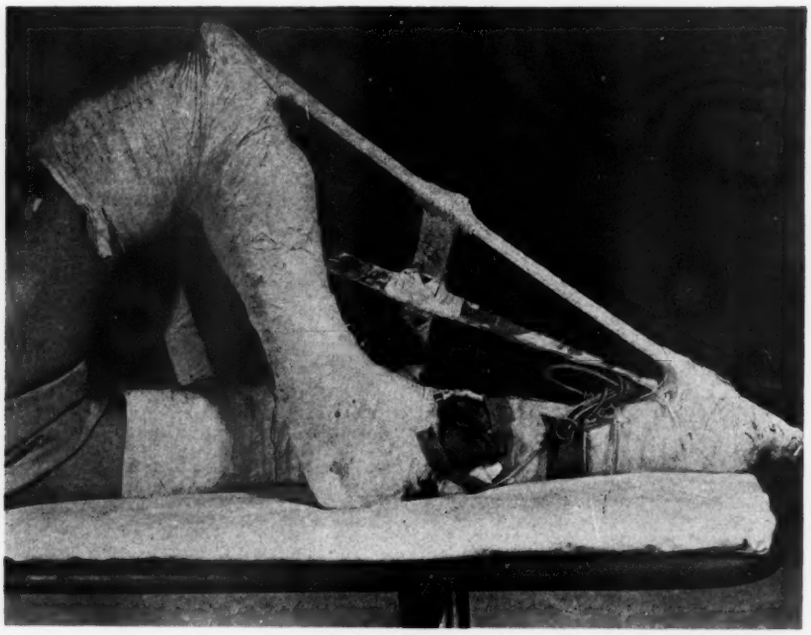

FIG. 1. This is not a cartoon of modern design. It exemplifies excellent engineering principles from the standpoint of good orthopedic immobilization. This patient necessitated a pedicle flap containing a fat pad to cover an extensive defect of his great toe. The simplest means to accomplish this end was to utilize a direct flap from the opposite calf. While this procedure gives an excellent end result, much could be said about the patient's comfort during the interval. It might also be added, that as a complication of the fixation, this patient developed an acute thrombophlebitis of the right lower extremity, and from this a small pulmonary embolus. This latter complication is not uncommon when awkward types of fixation inhibit normal muscular and circulatory activity.

The use of pedicle flaps is laborious, cumbersome, prolonged, and at times uncomfortable if the patient has to be fixed in an awkward position for a period of time. (Fig. 1.) However, when tendons, major nerves and blood vessels, and prominent bones such as the anterior surface of the tibia have been exposed, one should cover the defect with a skin graft to which is attached a good subcutaneous fat pad. This will entail the use of some variety of pedicle flaps. Again, if such a graft can be obtained nearby, a border flap frequently can be rotated over the defect and the donor area covered with a free graft. (Fig. 2.) This will eliminate construction of a distant tube pedicle or a flap from the opposite leg. Also, many

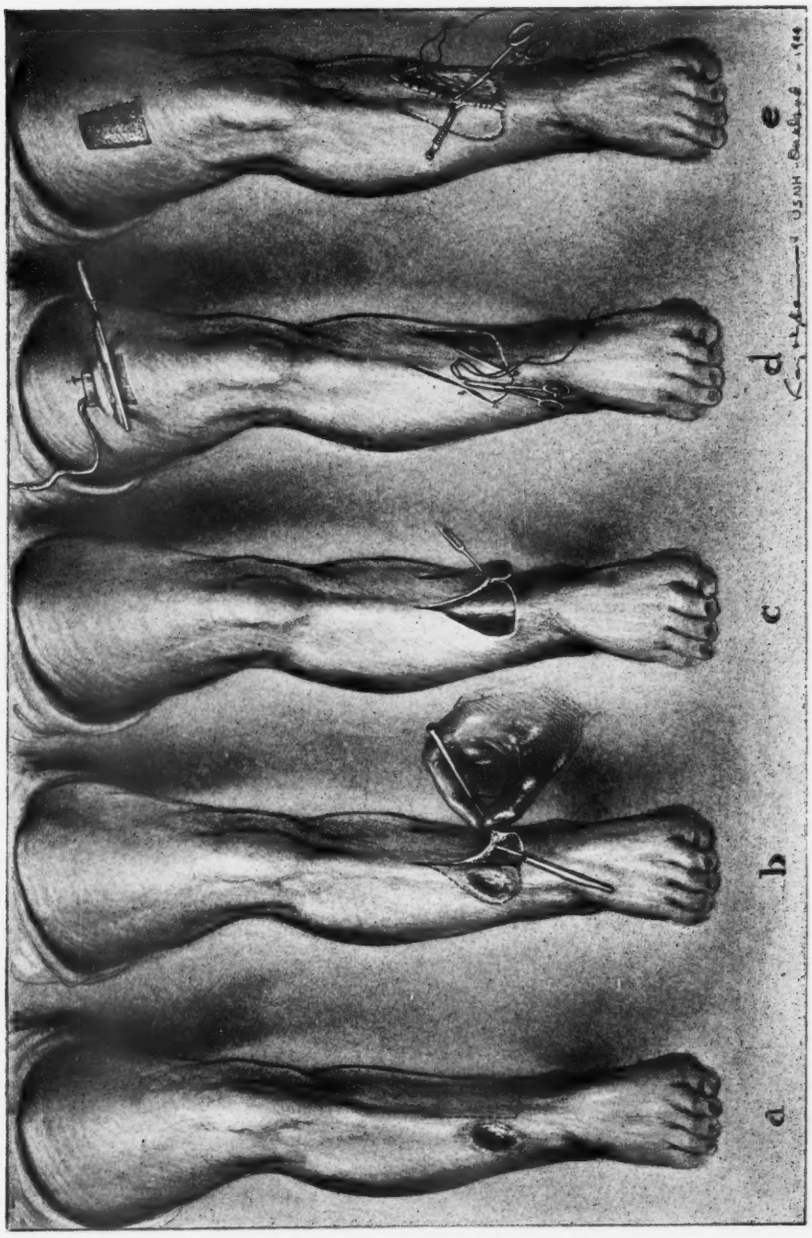

FIG. 2. Many defects over the leg can be covered simply and permanently by rotating over the surface a previously "delayed" border flap. The donor area can be covered with a split-thickness skin graft at the same operation.

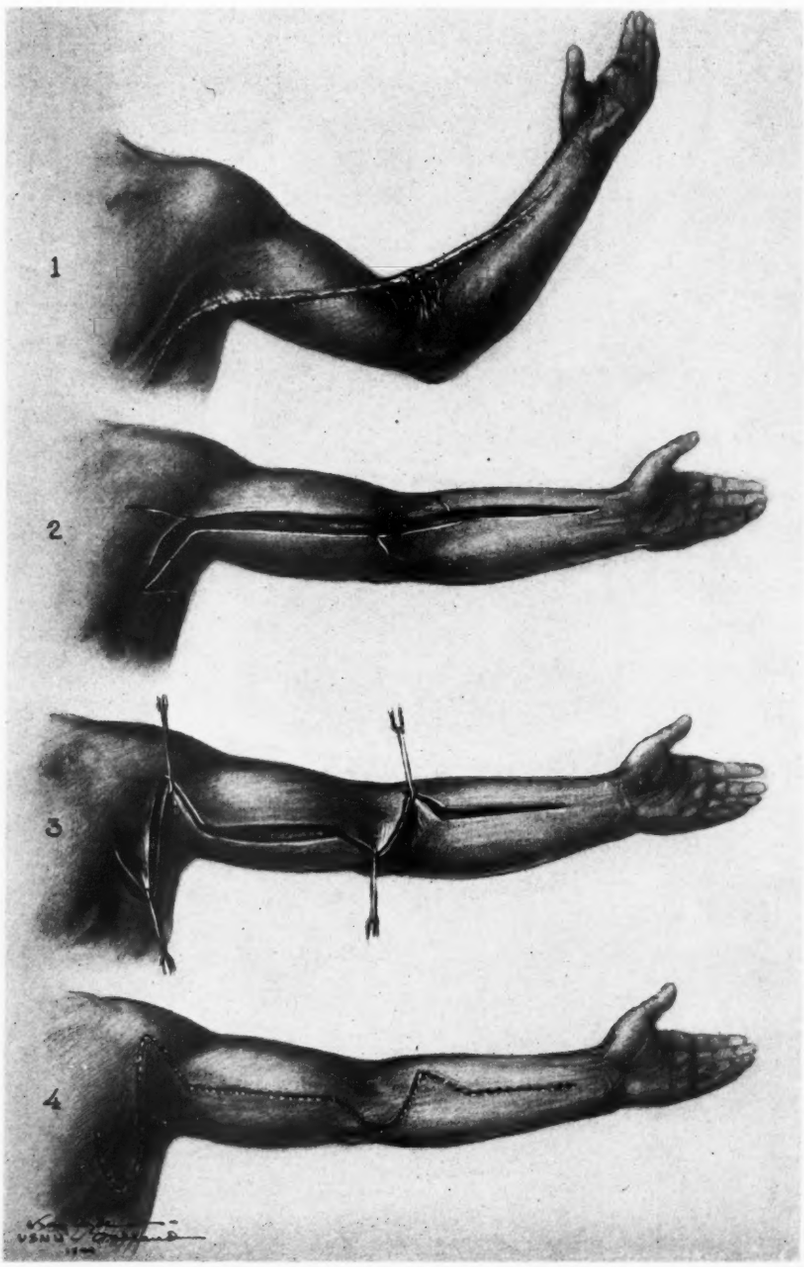

FIG. 3.—This patient was sent in with a long healed scar contracture that extended across both the cubital fossa and axilla. It followed an ill advised elective surgical incision. After complete excision of the scar, the straight line pull across the axilla and cubital fossa was eliminated by the construction of a double Z-plasty.

linear contractures may be corrected by a single or multiple Z-plasty (Fig. 3), thus again eliminating the necessity of bringing any new covering from a distant point.

Many deeper defects that follow burns will need future orthopedic, vascular, or peripheral nerve surgery. In anticipating this, a skin covering that will withstand reopening and other surgical trauma must be provided. Here again a type of pedicle flap must be utilized since its better blood supply will naturally allow for greater surgical liberties.

UNUSUAL COMPLICATIONS

While one might anticipate a wide range of sequelae associated with the management of burned patients who are severely ill, it has been gratifying to note that they have been relatively few. Several explanations may account for this observation. In the first place we have dealt chiefly with young individuals who were in good health at the time of injury. Excellent early management of the burns before being seen by us for late repair has done much to return a type of patient who responds rapidly when definitive surgery is undertaken. In addition, it should be mentioned that many of these extensively burned patients would have never reached our base hospital alive had it not been for the excellent clinical judgment used in the earlier care when plasma, blood transfusions and much hard work were contributed by those who carried out this portion of the treatment. Moreover, many extensively burned patients have arrived for plastic reconstruction that never would have survived before the days of plasma therapy. However, the three following unusual complications seem worthy of mention at this time:

The first of the interesting complications occurred in a twenty-two year old aviator who was admitted two and one-half months after having been shot down by an enemy pilot. He had suffered a complete loss of skin from the groin to ankle on each lower extremity. Before arrival here the granulations over both lower extremities were badly infected, the patient septic, anemic, and severely emaciated. He was prepared for skin grafting following the technic described above. One short skin grafting operation was performed at which time approximately 50 square inches of skin was placed over one knee and shin. Following this simple procedure, his temperature became normal and on inspection of his graft on the fourth postoperative day, we observed a 95 per cent "take."

The sutures were removed and the pressure reapplied. Two days later he developed another fever and within a few days thereafter, became deeply jaundiced. This we believed was due to a toxic hepatitis arising from the prolonged sepsis. Fortunately, the condition cleared with the aid of penicillin during the ensuing three to four weeks. Subsequently, the remaining defects have been covered without incident and the officer has been returned to duty.

Another patient, age forty-seven, developed an acute phlebitis following a simple skin grafting operation upon his ankle. Elevation of the part, hot fomentations, and massive doses of sulfathiazole gave rise to no improvement after forty-eight hours. The sulfathiazole was stopped and massive doses of penicillin substituted. The patient's temperature began to subside within four hours and was normal in eighteen hours. All tenderness along the course of the vein had disappeared completely and permanently two days after starting the penicillin therapy.

The third complication occurred in a young marine aviator. This officer had suffered third degree burns from his thigh to ankles of each leg when his plane had been shot down by the pilot of a "Zero." Upon admission to our hospital about two months after injury, each lower extremity was covered with badly infected granulations. The wounds and his general physical condition were prepared and the defects covered after several split-skin graft operations. During the course of the surgical procedures, it was noted that he had a foot drop on the right side. Neurosurgical consultation[6] was obtained and a definite lesion of the external popliteal nerve identified. It was believed that this lesion undoubtedly resulted from the heat of the original burn. In other words, while the nerve fibers were not interrupted by actual division, their conduction capacity was stopped as a result of the external physical insult. Time has proved this contention, since the function has gradually returned to nearly normal during the ensuing six months.

SUMMARY

1. Personal experiences in a rather wide group of burn casualties among naval personnel are discussed in detail.

2. Our observations in the management of (1) systemic damage, (2) repair of granulating cutaneous defects, and (3) the late correction of healed scar contractures are described.

3. Three cases of patients who developed unusual complications are presented.

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NOTE: Since presenting this paper we have been covering the granulatious with a special fine rayon silk as suggested by Dr. Neal Owens.[7] This material has approximately 150 meshes per square inch, making it sufficiently porous to permit drainage but at the same time, rendering it extremely nonirritating and comfortable for the patient.

LOCALIZED FIBROCYSTIC DISEASE OF THE FEMUR

A REPORT OF THREE PATIENTS TREATED BY CURETTAGE AND BONE GRAFT

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LOCALIZED fibrocystic disease of bone, or the so-called "bone cyst," is no longer considered a rare or unusual clinical entity. We believe it is sufficiently uncommon, however, to warrant this brief presentation of three interesting cases in which the patients were treated on the surgical service of an Army general hospital.

There are two distinct types of localized fibrocystic disease of bone: the solid lesions and the cystic lesions; but most authors believe that these simply represent different forms of the same non-generalized fibrous osteodystrophy. The solid lesions have been termed "polyostotic fibrous dysplasia."[7] Pathologically, these solid lesions are found to consist of a dense, grayish-white fibrous tissue containing a few bony trabeculae and completely replacing the normal medullary cavity of the bone in the region involved. One or many bones may be involved in the same individual, but in cases with multiple lesions, the involvement is predominantly unilateral. This well marked tendency to unilateral distribution lends credence to the theory that there is no hormonal basis for these lesions. Anatomically, these solid lesions may present themselves at any location in the affected bone.

In contradistinction to the solid lesions, the cystic lesions are usually fairly large fluid-filled cavities located in the shafts of the tubular bones. The cortex surrounding the lesions is thinned and expanded, and the cysts are lined by a thin connective tissue membrane. The fluid which fills the cavities is either clear and yellow or serosanguineous. These cysts are usually unicameral, that is, composed of a single chamber; but frequently there may be several partitions of fibrous tissue within the cystic lesion, dividing the cyst into several compartments. These cystic lesions are located nearly always in the shaft of tubular bones near the epiphyseal cartilage plate; and they very rarely extend across this epiphyseal plate.

In a growing bone, such a cystic lesion may appear to migrate toward the center of the shaft because normal bone may be laid down between the cyst and the epiphyseal plate. The proximal third of the humerus and femur are the most common locations for cystic lesions, although, of course, the lesions may occur in any bone.[6]

The pathogenesis of this disease is still an unsolved problem. A congenital abnormality of bone development, due to some primary germ cell injury or defect,[1,7] is probably the best solution as yet offered. It has been proved clinically that these localized bone cysts have little, if any, hormonal basis; certainly they are not due to any disturbance in the secretion of parathormone and are not to be confused with generalized osteitis fibrosa cystica (von Recklinghausen's disease).[11]

Some authors have suggested that these cystic lesions may be the healing forms of benign giant cell tumors.[5] The fibrous tissue lining the cyst, however, may contain a few foreign body giant cells but does not have the microscopic appearance characteristic of a giant cell tumor. Other investigators[10,11] have suggested that the cystic lesions represent a cystic degeneration of the solid fibrous lesions; but Jaffe and Lichtenstein[6] maintain that the fibrous tissue curetted from the wall of a cystic lesion is entirely unlike the tissue removed from a solid lesion. Hemorrhage into an area of softened bone has been offered as an explanation for the formation of cystic lesions,[3] but the cause of the softened bone remains a mystery. A few cases have been recorded in which no disease was noted at the site of a fracture until a month or two after the injury, at which time a cystic lesion became visible by *x*-ray. It is possible in such cases that an extensive hematoma within the medullary cavity of the bone may have organized and become cystic.[4]

Pommer[8] believes that mild trauma, not sufficient to produce fracture of a bone, may produce a focus of intramedullary hemorrhage. This focus becomes encapsulated and is kept distended by the transudation of fluid into it. Pressure from the cyst produces, in turn, a stagnation of blood and lymph, pressure erosion of bone and expansion of the overlying cortex.

Trauma and hemorrhage, however, are probably not the primary etiologic factors involved in the production of fibrocystic lesions of bone. As proof of this statement, in most cases there is no history of any previous injury to the affected bone; and although there are multiple bone hemorrhages in cases of hemophilia, cystic lesions do

not develop. It is probably better to assume that the fibrocystic lesions arise as the result of some local alteration in normal bone development. There is no evidence, either clinically or microscopically, to suggest that these lesions are truly neoplastic. Malignant degeneration has never been described in a fibrocystic lesion except in two cases mentioned by Allredge[2] in whom intensive roentgen ray therapy had been given. Although the condition may be thought to have a congenital origin, there is no clinical evidence to substantiate any hereditary transmission of the disease. An inflammatory origin of the fibrocystic lesions may be pretty well ruled out by the pathologic examination of tissue removed from the lesions, showing either no evidence of inflammation whatsoever, or occasionally a small focus of chronic inflammatory cells.

The occurrence of a fracture following a minor injury, such as a fracture through the proximal third of the humerus after throwing a ball, should make the clinician suspect the presence of a fibrocystic lesion. Such a pathologic fracture is often the first and only symptom of the disease. Many times, however, there is present a dull aching pain at the site of the lesion; and when the bones of the lower extremity are involved, a limp may be the first clinical sign. The roentgenographic appearance is quite characteristic: The area of bone involved has a rarified and often trabeculated appearance, with an expansion and thinning of the overlying cortex. One cannot tell, however, by *x*-ray examination alone whether the fibrocystic lesion is the solid or cystic type. Biopsy, of course, is the only absolute method of distinguishing a bone cyst from a neoplastic lesion of bone. From a roentgenologic standpoint, these fibrocystic lesions are indistinguishable from those seen in hyperparathyroidism except that the uninvolved portion of the bone is entirely normal and there is no evidence of generalized skeletal demineralization as is seen in von Recklinghausen's disease.

Interestingly enough, a non-union, or even a delayed union, of a pathologic fracture through a bone cyst has never been known to occur, despite the thin, expanded cortex and the replacement of the medullary bone by fibrous tissue or cystic fluid. In fact, there are many cases on record in which there was complete healing of the cystic lesion following the pathologic fracture; this does not occur, however, as frequently as one might hope it would. The fact that there is such remarkable improvement in the cystic lesion following the healing of the fracture justifies the delaying of any surgical

treatment of the lesion until it is seen whether or not the lesion will heal spontaneously. The healing of cystic lesions following pathologic fracture is believed to be due to the release of intracystic pressure, with its bone resorbing effect, and the stimulation of osteogenesis within the bone cyst.

Because these cystic lesions appear to be benefited by pathologic fracture, it seems logical to assume that good results should be expected from surgical treatment of the lesions. If the lesion is small, curettement alone may suffice; but when the lesions are large, as they usually are when pathologic fracture has either occurred or is imminent, curettement followed by the insertion of bone grafts is the treatment of choice. This is especially true in older individuals in whom the power of osteogenesis is lower than in younger individuals. Rogers[9] has employed massive tibial grafts in the treatment of two cases of cystic disease of the upper humeral metaphysis, the grafts acting both as an osteogenic agent and a means of internal fixation.

Cauterization of the cystic cavity is no longer considered necessary or advisable. In non-essential bones, such as a rib or the proximal end of the fibula, complete resection of the portion of bone containing the lesion is the preferred surgical treatment. *X*-ray treatment has not proved to be very successful in the treatment of bone cysts. Although pain, when present, is usually relieved by *x*-ray irradiation, epiphyseal arrest may occur following treatment, and malignancy may develop in cystic lesions treated by heavy irradiation. We concur with Allredge[2] that roentgen ray treatment of bone cysts should be employed only in the inoperable cases.

During the past year we have had occasion to treat three patients with localized fibrocystic disease of the femur. In two of the cases, the lesion was cystic in nature and involved the distal and proximal end of the bone, respectively. In the third case, the lesion was solid in nature and involved the mid-portion of the shaft. In all three cases, blood chemistry studies failed to show any alteration in the normal calcium, phosphorus and phosphatase levels; and roentgenograms of the other long bones, as well as the skull, failed to show any other cystic lesions.

CASE REPORTS

CASE 1. A twenty-one-year-old private was admitted as a patient to the hospital on March 5, 1942. He stated that he had never experienced

FIG. 1A

FIG. 1B

FIG. 2A

FIG. 2B

FIG. 1. Case 1. Roentgenograms of right knee. A, anteroposterior view; B, lateral view, taken three and one-half months following pathologic fracture through an extensive cystic lesion involving the supracondylar region of the femur.

FIG. 2. Case 1. Roentgenograms of right knee. A, anteroposterior view taken six months following pathologic fracture, showing remineralization of the bones but persistence of the large cystic lesion in the supracondylar region; B, anteroposterior view taken five and one-half months following curettage and bone graft.

any pain in his right lower extremity until January 4, 1942. On this date he was participating in an authorized baseball game, when another player slid into him, causing his right leg to buckle beneath him. He immediately noticed severe pain above his right knee and was unable to stand. He was taken to the local station hospital where *x*-rays revealed a fracture through the supracondylar region of the right femur. He was treated by Russell traction for a few days, and on January 13, 1942, a spica cast was applied.

The cast was removed on April 4, 1942, and physical therapy instituted to mobilize the right knee. Roentgenograms showed the fracture to be well healed; there was rather pronounced generalized osteoporosis of all the bones about the right knee; and in the supracondylar region, just proximal to the closed epiphyseal plate, there was a cystic lesion occupying almost the entire width of the shaft, with expansion and narrowing of the cortex in the medial supracondylar region. (Fig. 1*a* and *b*.)

The soldier slowly regained motion and strength in the right knee. By July, 1942, roentgenograms revealed that the bones about the knee were remineralized, but the cystic area in the supracondylar region remained essentially unchanged. (Fig. 2*a*.)

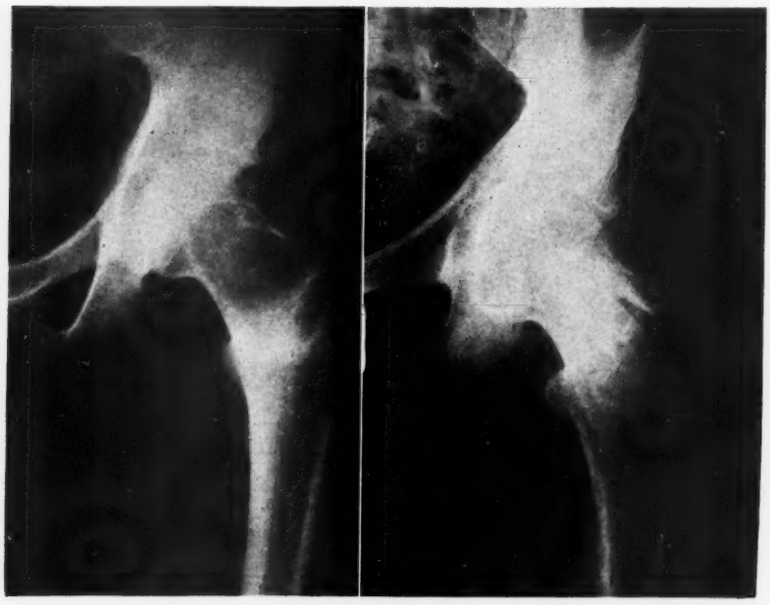
Because it was believed that the soldier could be returned to duty only after the cystic lesion was healed, surgical exploration of the bone cyst was performed on July 22, 1942. At operation, a section of bone, measuring approximately one inch (2.5 cm.) in diameter, was removed from the very thin cortex of the anteromedial aspect of the femur, just above the adductor tubercle. A multilocular cystic cavity was exposed. This cavity measured approximately two and one-half inches in diameter (6.3 cm.), was filled with clear straw-colored fluid and was lined with a thin layer of fibrous tissue. The cystic cavity was thoroughly curetted and almost filled with chips of bone removed from the shaft of the right tibia. A plaster cast was applied, extending from the mid-thigh to the toes. This cast was removed on September 16, 1942, and physical therapy was again instituted.

The soldier was discharged to duty on February 9, 1943. At this time he was walking without a limp, had 120 degrees of flexion in his right knee, and complained of only slight aching in the right knee followed prolonged use of the right lower extremity. *X*-ray examination at this time showed the cystic lesion to be well healed. (Fig. 2*b*.)

This case is of interest because the diagnosis of fibrocystic disease was not made at the time of the injury, although a review of the original roentgenograms did show the presence of the bone cyst in the supracondylar region of the femur. The bone cyst became more evident, however, after the demineralization of the femur which followed the immobilization of the lower extremity in a plaster cast. A pathologic fracture was not suspected at the time of the injury

because there was a history of trauma of sufficient magnitude to cause a fracture of a normal bone.

CASE II. A twenty-one-year-old private was admitted to the hospital



A B

FIG. 3. Case II. Roentgenograms of left hip. A, anteroposterior view taken on admission, showing large cystic lesion involving entire neck of femur; B, anteroposterior view taken four months following curettage and bone graft.

on November 27, 1943. He stated that he first noticed a dull aching pain in the region of his left hip on or about October 15, 1943. There was no history of any antecedent injury or illness, nor had he ever experienced a similar pain in any other bone or joint. He paid very little attention to the condition until about a month later, when the aching became so persistent that he reported on sick call for treatment. A roentgenogram of the left hip revealed a cystic lesion involving the entire neck of the femur, extending well up into the head and well down past the intertrochanteric line. (Fig. 3*a*.)

Because of the imminent danger of fracture through the neck of the left femur, the patient was placed at bed rest. On January 5, 1943, the neck of the left femur was exposed surgically through an anterior iliofemoral approach. The cortex of the femur in this region was of egg-shell thinness. Immediately upon puncturing through the cortex, a clear straw-colored fluid escaped; this fluid was under considerable pressure and pulsated with every heart beat. A window approximately one inch (2.5 cm.) in diameter was removed from the superior aspect of the femoral neck,

and through this window the contents of the cyst were thoroughly evacuated. This was a unicameral (single chamber) cyst, and the fibrous tissue lining was very thin. A portion of the left iliac crest, including the anterior superior spine, as well as the major portion of the lateral table of the wing of the ilium, were removed, cut into small pieces and packed into the cystic cavity. The cavity was almost completely filled with bone grafts.

A double hip spica cast was applied postoperatively. This was replaced by a single spica cast on February 17, 1944. A short spica cast, extending from the rib margins to the knee on the left, was applied on March 6, 1944, and physical therapy was instituted to mobilize the left knee and ankle. This cast was removed on April 6, 1944, and a walking ring caliper (ischial weight bearing) brace was applied to the left lower extremity. The patient is still wearing this brace. Roentgenograms show that the cystic lesion is becoming well obliterated by bone (Fig. 3*b*), but it was deemed advisable to prohibit weight bearing on the left lower extremity for at least five months following the operation because of the danger of fracture through the neck of the femur.

It is remarkable, in this case, that a pathologic fracture through the neck of the left femur had not already occurred prior to the patient's admission to the hospital. There was certainly very little bony support remaining in the femoral neck. It is also rather unusual to find the fluid within a bone cyst under as much pressure as was present in this case.

Case III. An eighteen-year-old private was admitted to the hospital on April 23, 1943, for further treatment of a simple fracture through the middle third of the right femur. He stated that he had never had any pain in any bone or joint prior to his present illness. On March 23, 1943, the soldier caught his foot in a rut while running during calisthenic drill, and fell to the ground, twisting his right leg beneath him. He immediately experienced severe pain in the right thigh and was unable to rise from the ground. He was taken to the local station hospital where roentgenograms of the right femur showed a pathologic fracture through a large cystic lesion in the middle third of the bone; there was very little displacement of the fragments. He was treated by adhesive traction in a Thomas splint for two weeks, and then a hip spica cast was applied. On May 26, 1943, a short spica cast was applied, extending from the rib margins to the knee on the right, and physical therapy was instituted to mobilize the right knee. The cast was removed on June 24, 1943, because roentgenograms showed that the fracture was well healed. (Fig. 4*a* and *b*.) A walking ring caliper (ischial weight bearing) brace was applied to prevent the patient from bearing much weight on the right lower extremity because of the danger of bowing at the fracture site.

The patient was permitted to leave the hospital on a seven-hour pass on July 10, 1943. Although he was walking with crutches and was wearing the caliper brace, he sustained another fracture of the right femur when he

A B

FIG. 4. Case III. Roentgenograms of right femur. A, anteroposterior view; B, lateral view, showing large cystic lesion with healed pathologic fracture two months after injury.

stumbled and fell down two or three steps at a private home. This second fracture was not at the site of the previous fracture but was through the proximal portion of the cystic lesion.

The patient was returned to the hospital by ambulance and was placed in bed with Russell traction on the right lower extremity. Because of a persistent respiratory infection it was not possible to operate upon the right femur until August 4, 1943. On this date, the proximal and middle thirds of the femoral shaft were exposed subperiosteally through a lateral approach. The cortex overlying the cystic lesion was found to be expanded and markedly thinned. A window, measuring approximately five inches (12.7 cm.) long and one inch (2.5 cm.) wide was removed from the lateral aspect of the cyst. The cyst was found to be filled with a yellowish, gritty fibrous tissue of rubbery consistency; there was no evidence of any fluid or any cystic areas within the fibrous tissue which filled the cyst. When all of this fibrous tissue was removed, there remained a cavity, measuring approximately six inches (15.2 cm.) in length and two and one-half inches

(6.3 cm.) in diameter, covered by a very thin layer of cortical bone. A large graft was removed from the left tibia and inserted into the cyst, extending well into the normal medullary cavity of the femur both above and below the cyst. The original fracture through the cyst was found to be well healed, but there was still motion present at the second fracture site. A portion of the outer table of the wing of the right ilium was also removed, cut up into small sections and inserted as bone grafts in the cystic cavity. With all this bone it was possible to fill only the anterior two-thirds of the cavity.

Microscopic examination of the tissue removed at the time of operation revealed a morphologic appearance in keeping with the fibrous repair of a bone cyst. The pathologist, Major G. D. Ayer, Jr., M.C., stated in his report: "The central portion is made up of loose connective tissue arranged in irregular fasciculi. As the periphery is approached, the connective tissue is denser and on the surface there are slender spicules of trabecular bone with cellular fibrous tissue in the interstices. From place to place there are collections of macrophages with foamy cytoplasm and occasional foreign body giant cells containing pigment. In at least one location the cortical bone is reduced to a very thin shell which is perforated in places and penetrated by the cellular connective tissue and bone spicules that form the outer portion of the lesion."

A double hip spica cast was applied following the operation. This was replaced by a single hip spica cast in six weeks. A short hip spica cast, extending from the rib margins to the knee on the right, was applied on November 4, 1943, and physical therapy was instituted to mobilize the right knee and ankle. The cast was removed on December 9, 1943, and a walking ring caliper (ischial weight bearing) brace was applied to the right lower extremity. The brace was removed on February 25, 1944.

Although there was definite evidence of bony repair within the cystic cavity, there was not complete obliteration of the cystic lesion by April 20, 1944. (Fig. *5a* and *b*.) There was an excellent range of motion in the patient's right hip and knee, but the patient complained of pain in these joints following a moderate amount of walking; and he was unable to walk for long distances without the use of a cane for support. He was discharged from the Army on a certificate of medical disability, since it was believed that he would never be able to perform the duties of a soldier even in a limited service capacity.

This case demonstrates well the use of a large intramedullary tibial bone graft both to promote osteogenesis within the cyst, as well as to maintain the position of the bone fragments following a pathologic fracture through the cystic lesion. It is also obvious that the roentgenographic appearance of this solid fibrocystic lesion

differs very little, if any, from that of the purely cystic lesions present in Cases I and II. One might suspect that the lesion in Case III would be solid instead of cystic only because of the location of the lesion

A B

FIG. 5. Case III. Roentgenograms of right femur. A, anteroposterior view; B, lateral view, taken eight months after curettage and bone graft. The massive intramedullary graft is still readily visible, and the cystic cavity is not yet completely obliterated.

in the shaft of the femur instead of in the metaphyses of the bone. The distinction between the solid lesion and the cystic lesion can be made only at the time of operation. Although the operation in Case III did not result in complete eradication of the cystic lesion, we believe that the operation has definitely increased the strength and stability of the femur, and further pathologic fractures through this site will no longer be imminent.

SUMMARY

We have presented three cases of fibrocystic disease of the femur. Two of these patients had a purely cystic lesion, while the third had a solid fibrous lesion. In each of the three cases, the lesion described was the only such bone lesion present, and there was no evidence of any endocrine or hormonal disturbance. Although the

gross and microscopic appearance of the solid lesion differs from that of the cystic lesion, it is probably true that both have as their pathogenic basis some localized congenital abnormality in bone development. The clinical picture in both types of fibrocystic disease is very similar, and the surgical treatment in both types is the same. Each of these three patients was treated by curettement of the fibrocystic lesion followed by insertion of multiple bone grafts. This type of operation resulted in complete obliteration of the two purely cystic lesions and almost complete obliteration of the solid lesion.

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REFRIGERATION IN TRAUMA

REPORT OF A NINE YEAR OLD PATIENT WITH LOWER EXTREMITY GANGRENE, FOLLOWING DISLOCATION OF DISTAL FEMORAL EPIPHYSIS

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THE utilization of refrigeration anesthesia in elderly patients afflicted with gangrene of an extremity, the result of diabetic or arteriosclerotic peripheral vascular disease, has become a recognized surgical procedure in the last three years. While in the fall of 1941 and in the spring of 1942 papers were presented on this subject at Omaha, Nebraska, and at Cedar Rapids, Iowa, without encountering a single surgeon familiar with the method, yet in the spring of 1943, when a similar paper was delivered before the Minneapolis Surgical Society, the author found that eight amputations under refrigeration anesthesia had been performed at the University Hospital in Minneapolis. Again, before the Oklahoma City Clinical Society in October, 1943, he learned that several cases of this nature had been amputated under refrigeration anesthesia in the University Hospital at the Oklahoma Medical School. Without a single exception, all the surgeons who had used the method were extremely enthusiastic about it.

The experimental studies published since 1938, by F. M. Allen,[1–9] of New York, combined with similar studies by B. Brooks and Duncan,[10,11,12] Wilson and Roome,[13] A. Blalock,[14] A. Blalock and Mason,[15] A. Blalock and Duncan,[16] and N. E. Freeman,[17] is chiefly responsible for the clinical acceptance of the chilling of tissues as a therapeutic measure. In 1941 and 1942, Allen and Crossman,[18] and Crossman, Ruggiero, Hurley and Allen,[19] and Crossman, Hurley, Ruggiero and Warden,[20] and finally Allen[21] in 1943, presented articles conclusively proving the value of refrigeration anesthesia. Further clinical observations on refrigeration anesthesia, with or without a tourniquet, have been published by McElvenny,[22,23] Tynes, Nichol and Wiggin,[24] Mock and Mock, Jr.,[25] Mock, Jr.,[26] Rupp,[27] and finally Richards.[28]

The latter's article appearing in The Annals of Surgery in February, 1944, has been called to this author's attention in numer-

ous letters as a condemnation of the method. A careful perusal of this article, however, shows a wholehearted acceptance of refrigeration anesthesia for amputations but a strongly critical attitude, based upon the study of two cases, concerning the use of refrigeration *with a tourniquet* in traumatized extremities where it is used for the control of infection either preceding or after reparative or reconstructive surgery. It is to be regretted that this author did not separate the proved and exceedingly valuable refrigeration anesthesia and the yet unproved and very doubtful maneuver of applying a tourniquet to a refrigerated extremity with a view of later removing the tourniquet without amputation. However, many experimental and clinical studies have demonstrated the value of refrigeration of an extremity *without a tourniquet* as a means of controlling infections, eliminating pain and shock, preserving certain parts of an extremity until collateral circulation has had time to become established, and even furnishing anesthesia for certain minor operations. Already we have abundant clinical proof of the efficacy of refrigeration in these conditions. But none of the experienced workers in this field has advocated or contemplated the use of a tourniquet with refrigeration, certainly not for more than the recognized physiological limit of time for these purposes. Refrigeration without a tourniquet is an entirely different situation from that depicted and criticised by Richards.

The following case is worthy of a detailed report because of the inherent dangers in this type of injury and the value of refrigeration in meeting the many problems presented:

CASE REPORT

F. W., a male, aged nine years, on March 4, 1944, while playing in a church yard, tripped over a wire and fell forward to the ground. Immediately pain and a definite deformity appeared about the right knee. He was taken to a nearby hospital where an *x*-ray revealed a complete separation of the distal epiphysis of the femur. A Thomas leg splint with skin traction was applied. Forty-eight hours later, under anesthesia, a closed reduction was attempted unsuccessfully. Again, traction was applied. On the eighth day a second effort was made to reduce the dislocated epiphysis by a method described by Smith, namely, acute flexion of the leg on the thigh. The next morning the surgeon noticed that the foot was cold and cyanotic. The leg was immediately placed in extension and heat applied to the extremity.

On the morning of the tenth day the author was called in consultation. The lad was suffering excruciating pain in the foot and leg, partially controlled by small, repeated doses of morphine. The patient's temperature

FIG. 1. Complete dislocation of distal femoral epiphysis with shaft of femur displaced distalward behind the dislocated and rotated epiphysis.

was 103°F. rectally, pulse rate 120, respirations 30. Examination of the throat, lungs, heart, abdomen and remaining extremities showed nothing abnormal. His white blood count was 19,000.

Examination of the right lower extremity showed bluish discoloration of the foot and ankle, with a gradual change from bluish to a dusky red appearance up to within a few inches below the knee joint. No pulsation could be felt in the popliteal, posterior tibial or dorsalis pedis arteries. Hypo-esthesia gradually merged into complete anesthesia from the knee

to the foot. There was some soft tissue swelling with definite bony deformity about the knee joint, especially in the popliteal space. Gangrene of the right lower leg was obvious, and it seemed probable that the gangrenous process would involve the entire leg.

Examination of the *x*-ray films showed the distal fragment pulled posteriorly and the shaft displaced behind it into the popliteal space. (Fig. 1.) The gastrocnemius muscle was attached chiefly to the posterior surface of the epiphysis and partly to the diaphysis. Thus, the pull of this muscle usually gives this characteristic displacement of the fragments when a complete dislocation of the epiphysis occurs. The displacement of the shaft of the femur behind the flexed epiphysis conceivably gives marked compression of the popliteal vessels and nerves.

As a consultant, the author was confronted with a case that had gone beyond the stage of mere congestion or beginning ischemia. Due to the long continued pressure on the popliteal vessels it was now a definite case of gangrene. Infection was imminent, if not present, in this extremity, as judged by the temperature and the excruciating pain. The entire lower leg had been wrapped in hot fomentations by the attending surgeon and kept very warm by an electric light bulb suspended in a cradle over the leg. Prior to his experiences with refrigeration, this is the therapy the author would have used. The same is true with the majority of surgeons. However, this heat was calling for a greater metabolic demand on the part of the tissues than could possibly be supplied by the retarded circulation. The moist heat sooner or later mascerates the skin thus opening portals of entry for infection. On the other hand, chilling of this entire lower extremity would place the part in a state of hibernation. The metabolic demands would be reduced to a minimum. The blood in the vessels, as proved by clinical experience and experimental work, would remain fluid. Bacterial growth or invasion would likewise be retarded. Cellular breakdown with the formation of histotoxins, the absorption of which is the most probable cause of shock in such conditions, would be minimized. Finally, a certain degree of anesthesia would develop in the part with disappearance of pain.

All of these factors were explained to the family physician and the attending surgeon. The moist heat was then changed to refrigeration. A large rubber sheet was placed beneath the leg, from the middle of the thigh to below the foot. Eight ice bags were placed about the leg, from just above the knee to the foot, four on the posterior and four on the anterior surfaces of the leg. The rubber sheet was then wrapped about the ice bags and the extremity, making it practically an insulated, air-tight compartment. The author did this refrigeration maneuver himself and at the same time instructed the nurses concerning the vital importance of keeping the part constantly refrigerated. In order to secure their co-operation the

rationale of refrigeration was carefully explained to them. Certain failures in the past have been due to the lack of this understanding and co-operation.

The question of immediate operation of the dislocated epiphysis was raised. In one way it seemed logical to correct the deformity and relieve the pressure on the popliteal artery as soon as possible. On the other hand, the boy was in a very serious condition from shock and probable infection. Time was needed to overcome these conditions. Furthermore, it was questionable if any of the lower leg could be saved. If the amputation site eventually was to be above the knee, it seemed more logical to amputate through the epiphyseal line rather than subject the patient to two operations. Again, there was the possibility of a stiff knee, in which case an amputation above the knee was more desirable. Therefore, it was decided to give the boy forty-eight hours, during which period a blood transfusion and the refrigeration should improve his condition for amputation. Conditions present definitely indicated complete occlusion of the popliteal artery and further delay would not jeopardize the limb.

Thirty-six hours after refrigeration started, the patient was transferred to St. Luke's Hospital. When admitted, the bluish to bluish-red discoloration extended to the level of the knee. It seemed to all who viewed it that the entire extremity was gangrenous and should be immediately amputated. Refrigeration, however, was continued and the extremity was never exposed to room temperature for more than two or three minutes.

The day after admission the nurse greeted us by saying, "The whole extremity looks lighter in color, especially just below the knee." Examination showed this to be true. It is characteristic of the extremity refrigerated without a tourniquet to change from the dark bluish discoloration to a pinkish-white pallor. Eventually, the line of demarcation becomes quite definite. The viable portion above is a pinkish-white without any cyanotic areas, while the portion below the line has a pale bluish, cyanotic appearance. Refrigeration was continued day after day on the boy's leg for two weeks. During this time we witnessed a gradual return of the pinkish-white color to the upper seven inches of his lower leg, indicating the gradual establishment of collateral circulation.

This phenomenon has been witnessed in at least five of the author's cases. We are prone to refer to it as "preservation of tissues." This term has been criticized. It must be emphasized that none of the advocates of refrigeration believe for one minute that dead tissue is preserved and eventually revitalized. As Crossman succinctly stated in a letter to the author, "Dead meat in the refrigerator is always dead meat." However, gangrene threatened an entire extremity, and inevitably occurred too often under our old methods of management by heat and the lack of control of infection; but under refrigeration, preservation of part of the tissues otherwise condemned is frequently witnessed because of the waiting period. Time is given for the compensatory enlargement or dilatation of the

collateral vessels with establishment of collateral circulation. No instance of complete securement of collateral circulation has been witnessed by this author or reported by others where true gangrene exists. Gangrene and infection which are spreading rapidly up a leg are halted by refrigeration, and the collateral circulation marching downward preserves tissue which otherwise would become gangrenous.

Twenty-four hours after admission to St. Luke's Hospital this boy was absolutely free of pain. His temperature varied from 99 to 100°F. rectally. He had absolutely no complaint of chilliness in the remainder of his body, due to the refrigeration. The second day an open reduction was done on the dislocated epiphysis. An effort was made to maintain reduction and yet re-establish knee function if possible. Furthermore, it had to be immobilized without interfering with the refrigeration and without risking pressure sores from a splint or cast.

At operation the patient was given morphine sulfate, gr. $\frac{1}{12}$, and scopolamine, gr. $\frac{1}{200}$, and a very small amount of nitrous oxide. The anesthetist remarked that even though a tourniquet was not applied, the refrigeration for eighty-four hours had anesthetized the part almost completely. An incision was made along the medial border of the quadriceps muscle, just above the knee joint, down to the bone. When the soft tissues were retracted, the condyles of the femur and the intercondylar notch presented in the wound. The short epiphyseal fragment was pulled downward and backward by the gastrocnemius muscle at almost a right angle. The shaft of the femur was displaced posteriorly and extended slightly distalward to the epiphysis. A Murphy skid was placed between the proximal end of the epiphysis and the distal end of the shaft, and the two were gradually raised into alignment. Flexion of the leg relieved the pull of the gastrocnemius muscle and allowed complete alignment of epiphysis and diaphysis.

Skeletal Pinning and External Fixation (Roger Anderson Apparatus). When the leg was straightened, both fragments tended to dislocate backward. In order to immobilize the fragments and at the same time leave the knee free for movement, a skeletal pin was passed through the condyles of the epiphysis, extending through the skin on both sides. A second pin was passed through the skin on the lateral surface extending obliquely downward through both cortices of the epiphysis but not through the skin on the medial side. Two skeletal pins were next passed through the lateral surface of the skin and through both cortices of the femur, the proximal one extending through the greater and lesser trochanters, and the second one angling upward through the shaft and lesser trochanter. External fixation rods were then applied to these distal and proximal units, as well as from the pin which transfixed the condyles and protruded through the medial aspect of the thigh. (Fig. 2.) This Roger Anderson apparatus remained on the boy's leg for eight weeks. No infection developed about the

pin sites. After amputation it was possible to give exercises to maintain knee function. During the above operation refrigeration of the lower extremity to within three inches of the knee joint was continued.

Refrigeration Anesthesia for the Amputation. Two weeks following admission to St. Luke's Hospital, the line of demarcation was well established and the day for amputation had arrived. The Department of Anesthesia feared the psychological effect upon this young patient if the amputation was performed with him awake. However, the author felt perfectly justified in giving this boy the same benefit of a shockless operation witnessed in many an old diabetic patient who had undergone amputation by refrigeration anesthesia. The entire lower extremity, from six inches above the knee to the foot, had been refrigerated for two weeks, therefore, the skin was well anesthetized. The resident applied a double fold of soft rubber tube as a tourniquet above the knee without the least complaint of pain from the patient. The ice bags were then removed and the rubber trough was filled with two buckets of finely cracked ice that completely surrounded the entire extremity, from three inches above the tourniquet to the toes. This procedure was carried out at 8:00 A.M. At 10:00 A.M. the author visited the patient. From this point on it is necessary to become quite personal in order to depict the dramatic situation and the methods used to avoid psychological injury.

Frankie said, "Why did Dr. Eastman take away the ice bags and put the ice around my leg?"

I replied, "That's a darned foolish thing for him to do. Now I'll have to take you upstairs and clean the leg all up, take away the cracked ice and put the ice bags back. How about it, do you want to go?"

Frankie was anxious for any new move or excitement that would take him from the children's ward, and, accompanied by the head nurse from this ward, we went to the operating room. Without any ostentation he was lifted onto the operating table and after the operating team had scrubbed, the cracked ice was removed, falling into a dishpan with a great deal of noise and much joking with Frankie. An anesthetic rack had been set up that prevented him from seeing the preparation of the leg for operation. All this time the head nurse, the anesthetist who was ready to give gas, if necessary, and one of the interns, were talking and playing puzzles with Frankie. The tourniquet was still in place and the operation was started. The soft tissues were cut and flaps formed without the patient's knowledge. In fact, he and I were having a great time joking and laughing at each other's jokes. When I took the saw in hand I realized that he might hear the sawing of the bone. Therefore, I suggested a little drumming. The intern upturned a basin and each took a pair of 8-inch artery forceps to see who could beat the best tune on the improvised drum. Frankie beat the harder and we even sang to his tune. Meanwhile, the bone was sawed through. The operation was finished and the little patient was lifted back

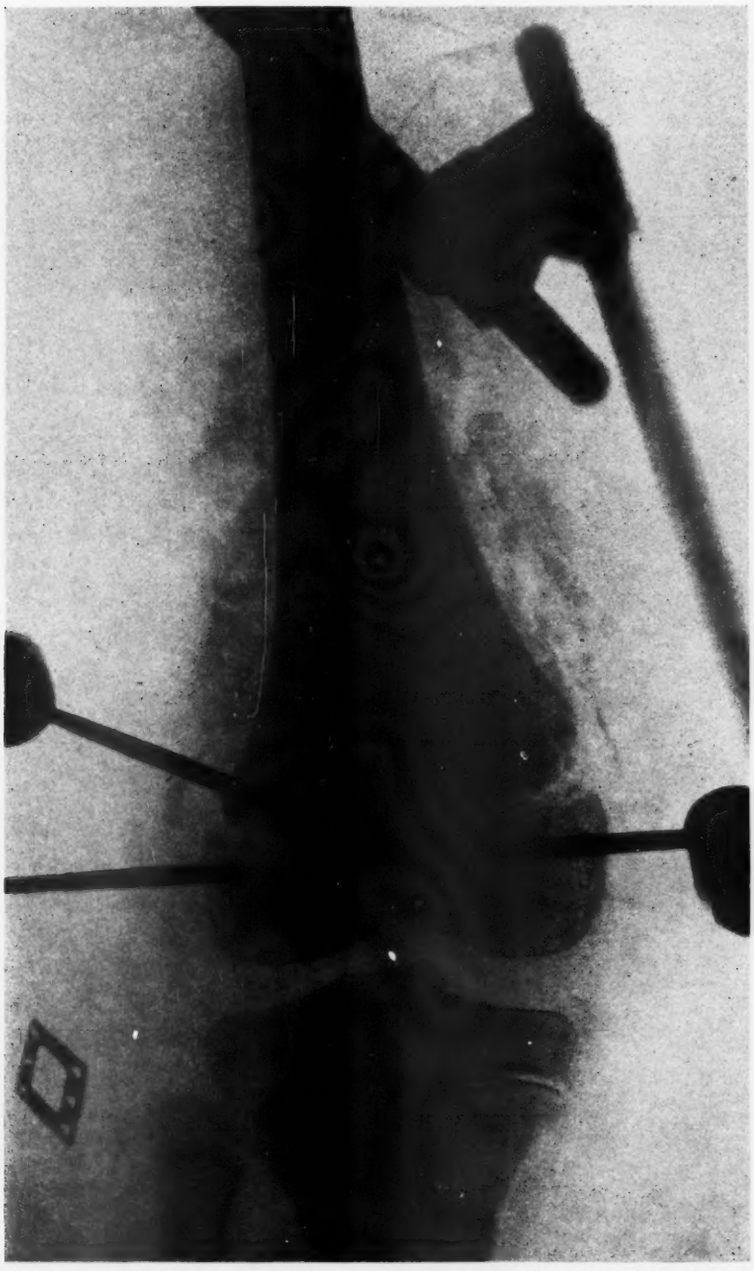

FIG. 2. *X*-ray film showing the reduction of the femoral epiphysis and its immobilization by means of skeletal pins and external fixation.

onto the cart with four ice bags applied around the stump. The operation was witnessed by at least eight visiting surgeons and interns and all were affected by the patient's complete absence of fear, any knowledge of the operation, and all remarked concerning the absence of shock. There was not even a change in the blood pressure which had been carefully recorded throughout the operation.

Thirty minutes later I went to the children's ward where the perturbed head nurse said, "Hurry in, Doctor, Frankie has just asked, 'Where is my foot?'" I went in and he repeated the question to me. I replied, "Frankie, you have two brothers over in the Pacific. If either of them had an old black foot like yours or the one you had, do you think they would want to keep it? And I'll bet that if either of them had to lose it, he wouldn't be as game about it as you were."

"Naw, they wouldn't keep it but they would be game all right," replied Frankie.

Two hours later the priest from the church where the boy was hurt visited him. He then came to me in the hospital and asked when I intended to amputate the leg. I told him it had already been done.

"Frankie is up there reading, and just the same as he was yesterday, and shows no sign of having been operated. You must be joking," he said.

The next day Frankie greeted me with, "When do I get my new leg?"

Never from then on did this patient show the least emotion over the loss of his leg. Psychologically speaking, there was never the least sign of a mental wound.

The skeletal pins were eventually removed. Perfect alignment between the diaphysis and epiphysis had been obtained. However, as Figure 3 indicates, the growth centers in the epiphysis have probably been destroyed. If this is true, any shortening that may develop in this extremity can be compensated for by lengthening the artificial leg. Exercises had been maintained throughout his convalescence. The stump of the lower extremity had been suspended in a hammock sling in order to preserve complete extension of the stump. As so often happens, there was a marked tendency to flexion deformity. By the end of four weeks the stump was completely healed. The stump could be completely extended and there was more than a 90 degree flexion at the knee joint. However, some eight weeks later a small sinus developed and a probe passed down this sinus led to the sequestra shown in the *x*-ray film in Figure 3.

Two weeks later the stump of this leg was again refrigerated over night, and the next morning a tourniquet was again applied above the knee and the stump surrounded with cracked ice. This was done with Frankie's consent and a complete understanding of its purpose. In giving his consent he modified it by saying that we could do the operation under refrigeration if he could watch it—"I'm going to be a doctor." Due to complications in the operation preceding Frankie's, the tourniquet was

in place three hours and fifteen minutes before we got to his operation. The stump and lower thigh to 3 inches above the tourniquet were completely surrounded by ice during this period. The sinus was dissected out

A B

FIG. 3. A and B, the *x*-ray suggests complete fusion between the diaphysis and epiphysis of the femur with probable restriction of growth in this femur. Note the two small sequestra at the end of the tibial stump.

and the sequestra removed with him watching the procedure. His only remark was, "It's just like working on a dead leg." Refrigeration anesthesia this time was used to prove the absence of previous psychological shock.

The lower thigh and stump have shown no deleterious effects from the three and a half hours of refrigeration and application of the tourniquet.

An artificial leg with a temporary socket is under construction. This boy will need very little rehabilitation as he has been thoroughly imbued with the spirit of rehabilitation.

CONCLUSIONS

1. A dislocated femoral epiphysis, like a dislocated knee, may be followed by gangrene of the lower extremity. As in one of the author's cases of dislocated knee, the original trauma may tear the intima loose within the popliteal artery, thus gradually damming the blood stream followed by a late thrombus and gangrene. In this case the popliteal artery showed no external evidence of injury. Again, the traumatizing force responsible for the dislocated epiphysis, or knee, may cause direct trauma to the popliteal vessels with their occlusion. Finally, the continued pressure of the dislocated parts on the popliteal vessels may be the etiological factor for the resulting gangrene. Complete dislocation of the distal femoral epiphysis must be reduced early and usually by open operation.

2. When gangrene follows such a disaster, it spreads rapidly to the level of the popliteal space. Heat treatment, by calling for more blood supply, may stimulate collateral circulation, but it also adds to the danger of infection. Refrigeration places the tissues of the extremity in a state of hibernation, reduces metabolic demands, holds infection in abeyance and gives time for the establishment of the collateral circulation that may preserve a part of the extremity. In this case we feel positive it preserved six to seven inches of the lower extremity.

3. Refrigeration without a tourniquet can be continued indefinitely *without* deleterious effects upon the tissues. Refrigeration in this case, at the third operation, allowed the tourniquet to be applied for three hours and a half about the thigh without the least sign of damage to any of the tissues at or below the tourniquet site. Future experience may prove this to be a valuable method in the control of a spreading infection from an injured extremity, not gangrenous, and with the extremity living after the tourniquet is removed.

4. The skeletal pinning and external fixation in this case allowed the preservation of knee function which is so essential if full benefit from the prosthesis is to be obtained in these lower leg amputations.

5. This nine-year-old patient proves that refrigeration anesthesia is applicable to the young as well as to the old. It has its place in traumatic as well as in diabetic gangrene. In either instance the

amputation can be performed under refrigeration anesthesia without a particle of shock, either physical or psychological.

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SURGERY AT A HIGHER ALTITUDE

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CAMP Hale, of which the Station Hospital is a part, is located high in the Rocky Mountains at an altitude of approximately 10,000 feet. When the hospital was opened there arose questions as to the effect of this altitude on various phases of surgery. Speculations began concerning the use of anesthetic agents, alterations in wound healing, alterations in fracture healing, postoperative complications, sterilization methods and variations in laboratory findings. Although there are small hospitals in nearby towns and villages where surgery is done, none of them had surgery performed on a large organized scale as was to be the destiny of this hospital. Since there were no available guides to follow in answer to many of the questions, the establishment of the surgical service was somewhat of a pioneering project.

Some of the physical characteristics of the atmosphere at the elevation of this camp are shown by comparison with sea level standards. The barometric pressure is reduced from 760 mm. of mercury to about 522 mm. of mercury. The percentage of oxygen in the air is the same as at sea level; viz., 20.93, while the oxygen partial pressure in the air is reduced from 160 to about 109 mm. of mercury. The oxygen partial pressure of alveolar air is decreased to approximately 60 mm. of mercury. The dryness of the air results in rather marked dryness of the mucous membranes of the upper respiratory tracts until acclimatization takes place.

The choice of anesthetic agents was of great importance. Ether, alone or in combination with nitrous oxide and oxygen, was used early in the development of the surgical service. When it was administered by the open drop method, it was found that about twice the usual amount needed for an ordinary operation was required at this altitude. Volatility of the ether seemed increased in the dry atmosphere and frost quickly collected on the mask. When ether, alone or in combination, was used for surgical anesthesia, cyanosis developed more readily than has been observed by the author at lower levels. The use of inhalation anesthetic agents was made more difficult by the lack of experienced anesthetists. The

choice of other agents became necessary. The surgeons administered their own local and spinal anesthesias while the patients were watched and checked by nurses or surgical technicians during the operative procedures. The extent of use of the agents used over a period of eighteen months is shown in Table 1.

TABLE 1

	Times Used	Minor Complications	Major Complications	Deaths
Local (novocaine)	1076	0	0	0
Spinal:				
a. Procaine HCl	681	62	1	0
b. Pontocaine in glucose	321	20	0	0
Sodium Pentothal I.V.	125	0	0	0
Topical	216	0	0	0
Nerve or field blocks	54	0	0	0
Ether	5	cyanosis	0	0
Nitrous oxide-oxygen	1	cyanosis	0	0
Gas-ether-oxygen	4	cyanosis	0	0

It will be noted that cyanosis developed fairly consistently with inhalation anesthesia. There were no complications observed in the use of local, field block or nerve block anesthesia. Of the 681 procaine HCl spinal anesthesias, sixty-two showed minor complications manifested bynausea, vomiting or both. There were thirteen patients with blood pressure drops sufficient to give a syndrome of symptoms resembling mild shock. One orthopedic patient apparently developed a marked decrease in blood pressure, rapid pulse, thirst and pallor sufficient to be classified as a severe reaction. The patients having pontocaine in glucose had twenty minor reactions such as nausea, vomiting, blood pressure decreases and pallor. There were eleven failures with procaine HCl and four failures with pontocaine in glucose. Supplementary agents were used, such as local novocaine, sodium pentothal intravenously, and least of all, inhalation agents. There were no anesthetic deaths.

Operative experience soon proved that wound healing was not altered by altitude changes. Out of 1,276 operations classified as major procedures and 1,684 as minor procedures, there have been only nineteen primary wound infections. Serum pockets or small hematomas occurred in twenty wounds. One compound fracture of the radius and ulna, treated surgically by débridement and open

reduction with a bone plate, developed gas gangrene. This patient's life was saved but a supracondylar amputation had to be done. The treatment of primary and secondary infected wounds resulted in wound healing as would be expected at usual altitudes. The use of sulfanilamide crystals for wound frosting after débridement and hemostasis allowed the primary closure of accidental wounds which could not otherwise have been closed.

Training on rugged terrain at this camp resulted in an ample number of fractures, treated and observed, to conclude that bone healing is not delayed. Delays which resulted in the slow return of some patients with fractures to duty are explained more by the amount of ligamentous and soft tissue injury by the same forces that produced the fractures. Especially in fractures resulting from skiing, there must be tremendous tension and bending forces exerted before the fracture occurs. This is evidenced by the great amount of soft tissue swelling accompanying these fractures. There have been a minimal number of delayed or non-union of fractures. At a mining camp not far from this camp site, it has been considered, without proof, that fluorides in the water supply alter bone healing. The water supply at this camp does not contain the fluorides.

Surgical complications that have occurred are no different than those observed in any hospital at lower altitudes. The complications that have occurred in 2,980 operations are shown in Table II.

There is a total of 193 postoperative complications of which ninety-eight, or nearly half, are concerned with the respiratory system. The small number of cases with atelectasis and pneumonia is considered to be the result of a rigidly enforced program of postoperative care. The one pulmonary infarct occurred in a patient who had a ganglion removed from a wrist. This procedure was performed under local anesthesia and the patient was ambulatory throughout his convalescence. The infarct occurred on the eighth postoperative day. The one patient with pulmonary embolism occurred on the ninth postoperative day following an appendectomy. The onset was rapid and death ensued in less than two hours.

Although the infectious diseases were few in number, they caused considerable concern. One patient developed appendicitis and required operation during the full-blown stage of exanthema of measles while the others followed operations. One scarlet fever patient developed an acute gangrenous appendicitis in the early desquamative stage of his rash. This patient developed postoperative intestinal

obstruction which was relieved by the Miller-Abbott tube. Rheumatic fever complicated the convalescence of a patient with a gunshot wound of the foot. Even though the postoperative courses of these patients were long and difficult, recovery was accomplished.

TABLE II
Postoperative Complications

Type of Complication	Name of Complication	Incidence	Total Number
I. Respiratory	Upper repiratory infection	82	
	Atelectasis	6	
	Bronchopneumonia	4	
	Atypical pneumonia	3	
	Lobar pneumonia	1	
	Pulmonary infarct	1	
	Pulmonary embolus	1	
			98
II. Infectious diseases	Measles	4	
	Scarlet fever	1	
	Rheumatic fever	1	
III. Wound complications	Primary wound infection	19	
	Serum pockets	16	
	Secondary wound infection	18	
	Hematomas	4	
	Primary postoperative hemorrhage	6	
	Secondary postoperative hemorrhage	2	
	Gas gangrene	1	
	Hemarthrosis	1	
			67
IV. Miscellaneous	Tonsillitis	5	
	Stomatitis	2	
	Serum sickness	2	
	Cystitis	1	
	Reaction to Na morrhuate	1	
	Abscessed tooth	1	
			12
V. Gastrointestinal complications	Paralytic ileus—postoperative	4	
	Intestinal obstruction	2	6
VI. Deaths		4	4

Wound complications were kept at a minimum for such a volume of surgery. In all clean surgical cases careful attention was given to aseptic technic, sharp dissection, hemostasis and careful approximation of tissues in the suturing of wounds. In the surgical care of potentially infected or contaminated wounds débridement, cleansing,

use of sulfanilamide crystals, and careful suturing resulted in primary healing in the majority of instances. These factors, together with the use of the finest suture materials, resulted in good wound healing.

There have been four deaths on the service. One was due to pulmonary embolism as previously mentioned. Another patient was operated upon for a dynamite blast wound which produced an evisceration, severe injury to his eyes, and loss of fingers of both hands. Death was demonstrated at the postmortem examination to have resulted from a severe concussion with edema and petechia scattered through the brain tissue. The remaining two deaths resulted from severe chest traumas which were not operated upon.

The sterilization of material and instruments for aseptic surgery is accomplished by steam pressure sterilizers at eighteen to twenty pounds of pressure with temperatures of 240 to 250°F. Sterilizing time of forty-five to sixty minutes is routinely used. It is unsafe to use boiling for instrument sterilization since the temperature at the boiling point is about 186°F. at this altitude. All items required in sterile technics are routinely cultured twice per week for aseptic control.

It is sufficient to say that blood shows a slight elevation in the red blood cell count and hemoglobin. The differential blood counts show no variation beyond that which has been seen at lower altitudes. There are no evident changes in blood chemistry. Basal metabolism studies are most affected by the atmosphere at this altitude. The manufacturer of the basal metabolism machine attempted to overcome these changes by recalibrating the instrument but results have not been satisfactory.

The general surgical lesions requiring operations which are commonly seen in the men of military age are for the most part congenital defects. Such defects include hernias, hemorrhoids, varicose veins and varicoceles. Soldiers are inducted with the potential defects which develop under the stress and strain of rigorous training. It has been impossible to determine whether the added element of mountain climbing in the training program contributes to the development of hernias. There have been 235 hernia (inguinal) repairs among 189 men in about eighteen months. Of this number fifty-six were bilateral inguinal hernias, one accompanied a hydrocele, and fourteen were present with varicoceles. Over 50 per cent were direct types. An attempt to make a follow-up study was carried

out with the uncertainty of assignment, transfer and movement of troops. However, at this camp, many men who were operated upon remained at or returned to the camp to make the study of more value than could be ordinarily expected. Of the 189 patients 125 were doing full duty without evidence of symptoms or recurrence; fifty-five were transferred to other field units and nine were disposed of by certificate of disability discharge because of psychoneurosis. Although about ten men complained of a tightness or pulling sensation in the region of the scar, there were no known recurrences in the entire group.

In all these hernia repairs only five primary wound infections occurred. One occurred in a repair of recurrent hernia originally operated upon before induction. Two were unexplained. There have been no extrusions of non-absorbable sutures except in one case. Secondary incisions were required in two cases to remove deeply buried sutures causing a chronic sinus. Healing resulted quickly after the removal of the buried sutures.

The medical service of this hospital diagnosed and treated 252 atypical pneumonias, sixty-nine bronchopneumonias and fifty-three lobar pneumonias in about eighteen months. Among these were ten pleural effusions and two empyemas. All effusions were treated by the surgical service. The simple effusions required from one to six thoracenteses for recovery. One of the empyemas complicated a streptococcic lobar pneumonia. Cultures of the fluid showed a virulent hemolytic streptococcus while *x*-ray studies demonstrated multiple pockets of fluid. The repeated aspiration of pus from all pockets, local instillation of penicillin, and general administration of penicillin resulted in a cure without further surgery. It was noted that cultures of pleural pus after the first intrapleural dose of 25,000 units of penicillin became negative. The second empyema complicated a pneumococcic lobar pneumonia. There was a massive effusion of pleural pus with mediastinal shift and severe respiratory embarrassment. At the height of this soldier's illness, unconsciousness developed and an heroic attempt at relief was made by doing a thoracentesis without anesthesia of any kind. Thirteen hundred cc. of thin pus were aspirated. It was expected that this patient would die but within four hours consciousness was regained and recovery began. Repeated aspirations and penicillin therapy, local and general, has resulted in recovery without further surgery. Each of these two empyemas due to different organisms have required one

million five hundred thousand units of penicillin. The free use of oxygen was required as a supportive measure in all these patients because of the mechanical reduction of vital capacity by the effusion and the decreased oxygen partial pressure of alveolar air at this altitude. The author believes that if all empyemas can be halted in their development and cures be obtained by this type of therapy, the mortality rate of empyema by other methods of treatment will be reduced to a minimum.

CONCLUSIONS

1. Surgery may be performed at higher altitudes with equal results of surgery at lower altitudes.

2. Wound healing and fracture healing are not disturbed by any oxygen variations at higher altitudes.

3. Two cases of empyema of severe types caused by pneumococcus and streptococcus hemolyticus have been cured by the relatively simple procedure of thoracentesis and penicillin therapy.

4. Follow-up study, as could be done in the armed forces, of 235 hernia repairs has shown no recurrences and only five wound infections

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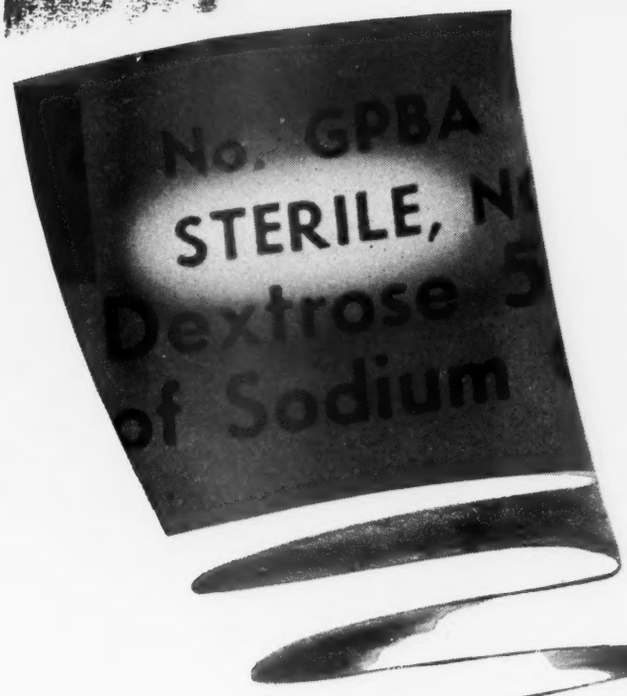

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*Reiter, P. J., Experience with Benzedrine, Ugeskr. f. laeger, 99:459-460, 1937

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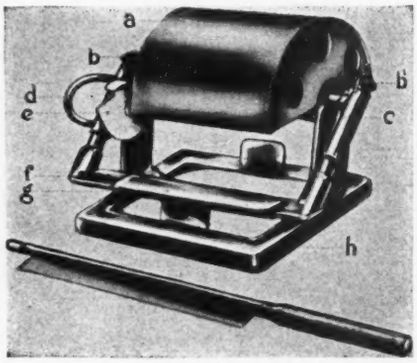

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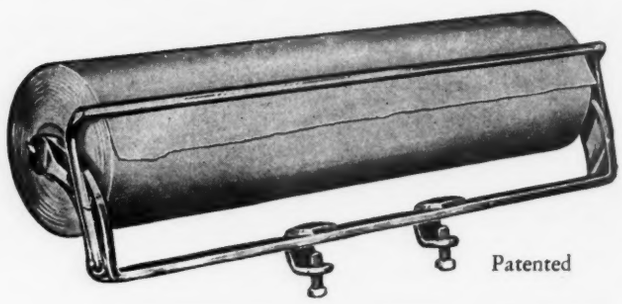

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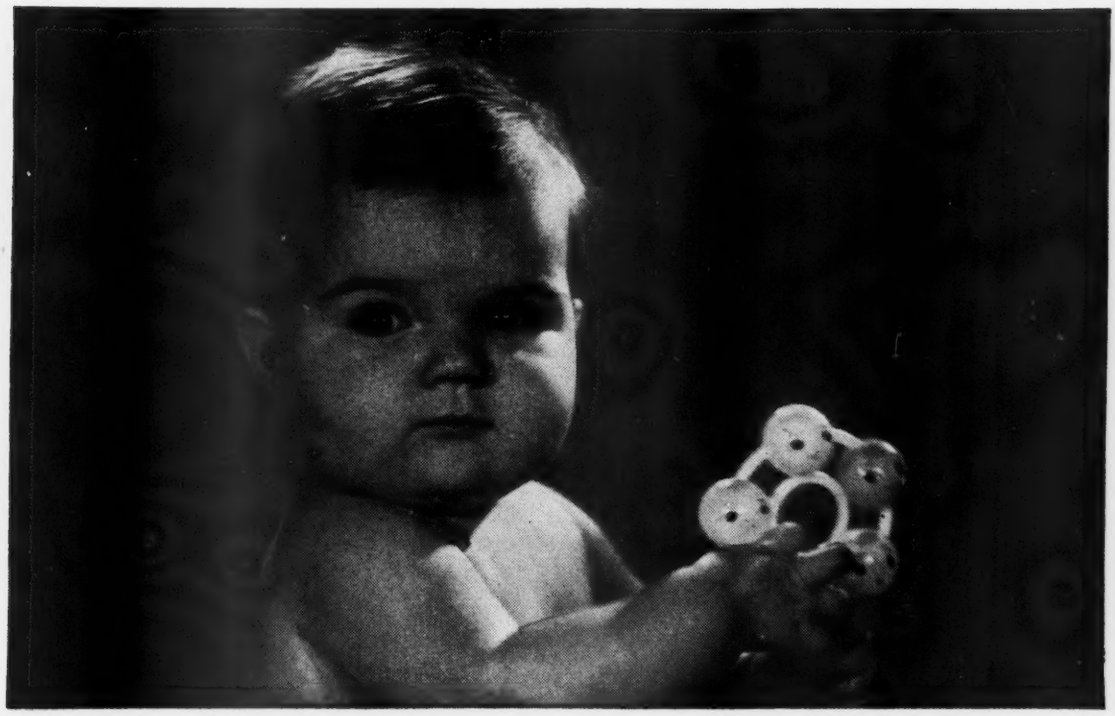

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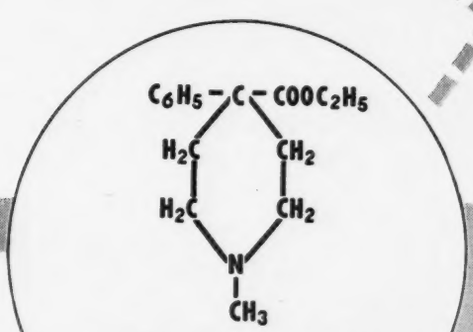

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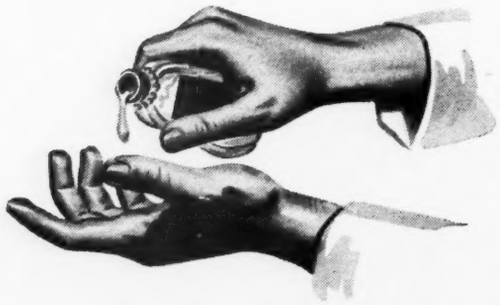

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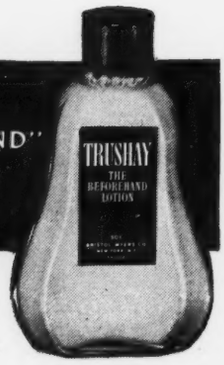

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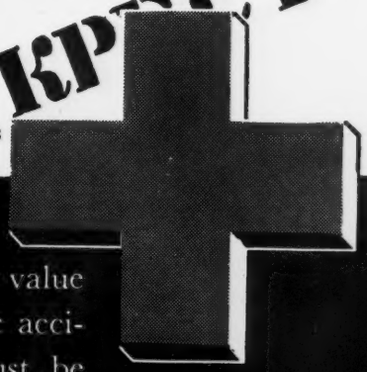

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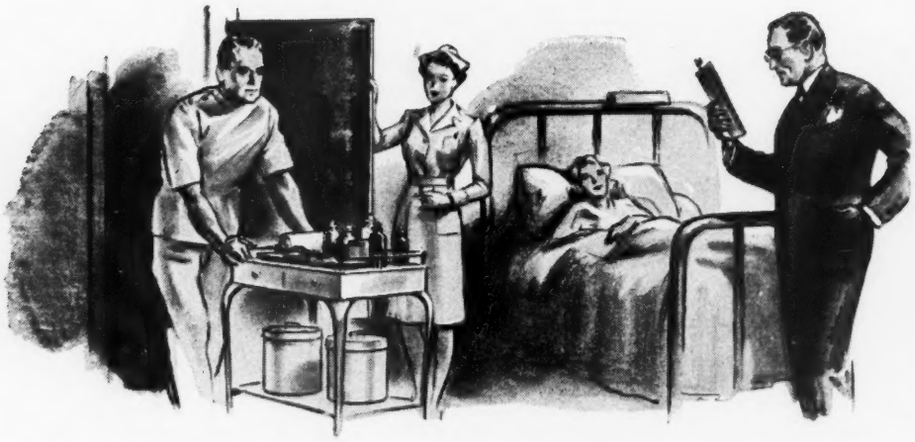
Vitamin G (0.50 mg.)	500 micrograms

together with liver concentrate (vitamin fraction), derived from 4 grams of fresh liver and dried brewers yeast.

IN THE PREVENTION OF

Postsurgical Anemia



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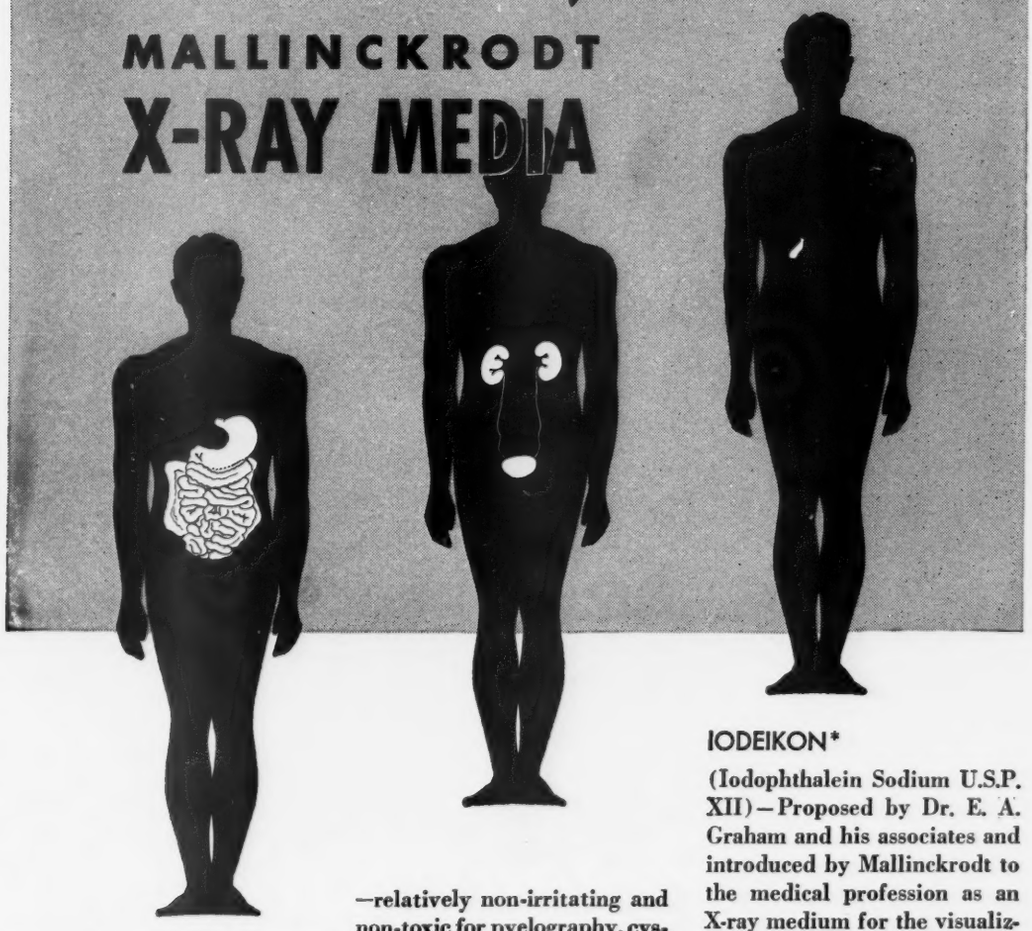

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(12 grams of Hippuran* dissolved in 25 cc. distilled water.) Literature references as to recommended technic, indications and contraindications sent on request.

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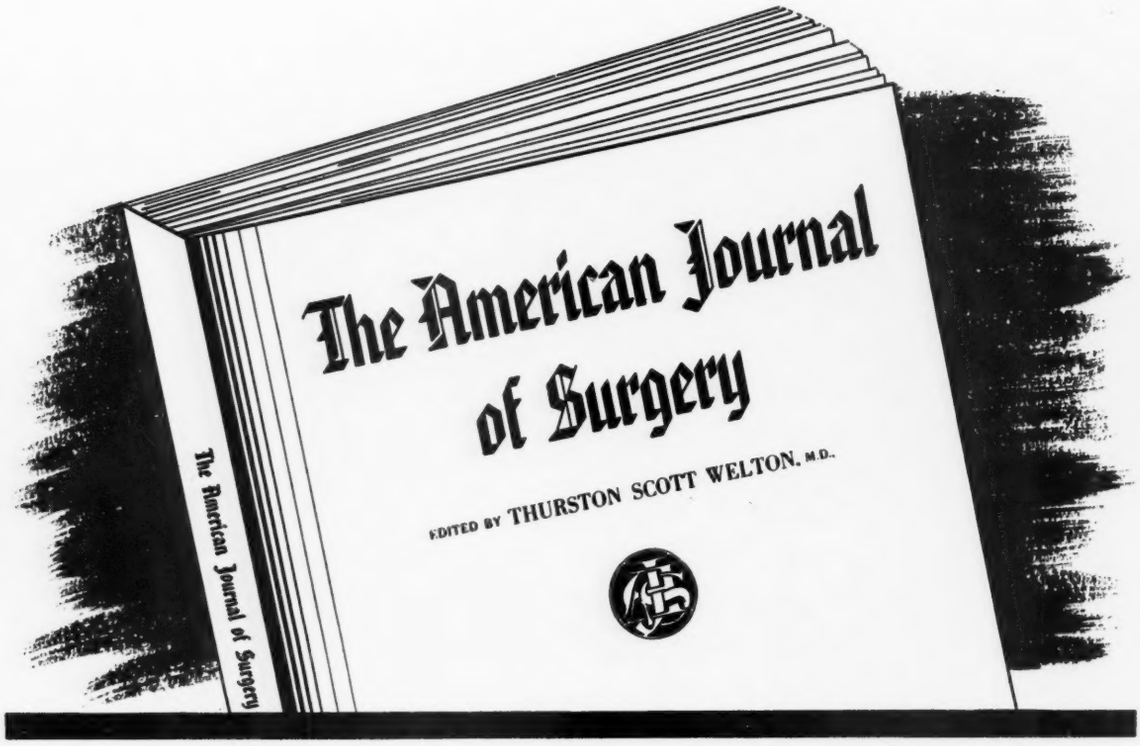

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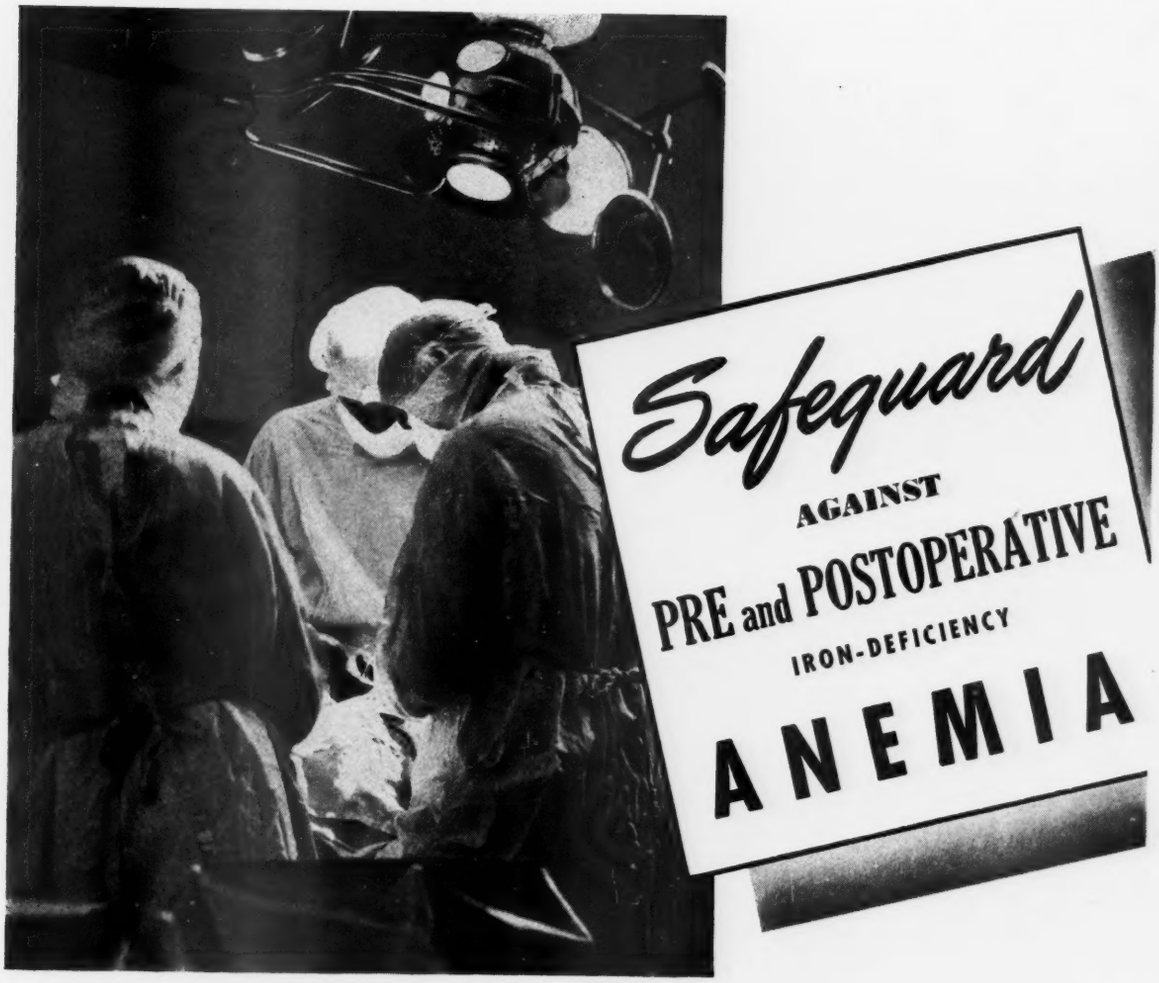

Iron-deficiency anemia is a factor to be considered in pre and postoperative conditions. Hence, we suggest that you prescribe Copperin routinely for a period preceding and following surgery. Copperin stimulates the hematopoietic system—provides material for replacement of hemoglobin—increases the red blood cell count.

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(1). Spies, Tom D.; Cogswell, Robert C., and Vilter, Carl: J.A.M.A. (Nov. 18) 1944. Spies, Tom D.: Med. Clin. N. Am. 27:273, 1943. (2). Jolliffe, Norman, and Smith, James J.: Med. Clin. N. Am. 27:567 (March) 1943.

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